EARTHQUAKE REAUTHORIZATION FOR FISCAL YEAR 1988

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

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MARCH 10, 1987

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*Ranking Republican Member.
**Resigned February 19, 1987 (H. Res. 89).
***Elected March 30, 1987 (H. Res. 133).

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EARTHQUAKE REAUTHORIZATION FOR FISCAL YEAR 1988

TUESDAY, MARCH 10, 1987

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:42 a.m., in Room 2318, Rayburn House Office Building, the Honorable Doug Walgren (chairman of the subcommittee) presiding.

Staff present: Carrye Brown, professional staff member; David Goldston, professional staff member; Maryanne C. Bach, Republican science coordinator.

Mr. **Walgren**. Let us begin and I apologize for the delay. The ranking minority member has been delayed this morning, so we should start.

As you know when the Congress enacted the Earthquake Hazards Reduction Act of 1977 and established the National Earthquake Hazards Reduction Program, it recognized the need for a comprehensive and an integrated national program to reduce losses resulting from earthquakes.

With a decade having past and about $549 million dollars being spent, we ought to be looking in detail at the progress that Federal agencies have made in addressing that problem.

In addition, in this hearing today, the subcommittee will review the direction of on-going projects, large multi-year projects underway and the impact of the fiscal year 1988 budget proposals which reduce the earthquake prediction effort at the U.S. Geological Survey and reduce also state and local preparedness activities at the Federal Emergency Management Agency.

We also want to look at the implementation of the Earthquake Act. Implementation of this legislation is very complex since it involves so many Federal agencies as well as having so much to do with State and local efforts.

Each of these levels has a specific responsibility and duties and maintaining the balance between them is essential for an effective operation and we literally don't know how we are doing on that.

Although earthquake hazards are most frequently associated with California, we all know that portions of most of our states, 39 states, 70 million people, are as a practical matter at risk and the risk to life and property are as great now as when the bill was passed and the need for a coordinated national approach is certainly no less.

The infrequency of catastrophic events like earthquakes, tends to produce an approach and a feeling of neglect and it is the responsibility of each of us to ensure that this kind of neglect does not interfere with the efforts that a prudent person would make to protect the future.

Investment in measures to mitigate the effects of earthquakes can result in great savings should that event happen and certainly, we are all in pursuit of the savings of lives that we know are in danger if such an event happens.

In the longrun of 50 and 100 years, most would believe that it will happen and it is not a question of if and so it pays to be prepared.

[The prepared opening statement of Mr. Walgren follows:]

OPENING STATEMENT
FOR THE
HONORABLE DOUG WALGREN (D-PA)
ON
THE EARTHQUAKE HAZARDS REDUCTION ACT AUTHORIZATION

March 10, 1987

When Congress enacted the Earthquake Hazards Reduction Act of 1977 and established the National Earthquake Hazards Reduction Program (NEHRP), it recognized the need for a comprehensive, integrated National program to reduce losses resulting from earthquakes. With a decade having past and about $549 million expended, it is time to take a detailed look at the progress federal agencies have made in addressing the Nation's earthquake hazard.

In addition, in this hearing today, the Subcommittee will review the thrust of on-going projects, large multi-year projects underway and the impact of the FY 1988 budget proposals, which reduce the earthquake prediction effort at the U.S. Geological Survey and state and local preparedness activities at the Federal Emergency Management Agency.

We will also look at the implementation of the Earthquake Act. Implementation of this legislation is very complex, since it involves coordination between four federal agencies, as well as state and local governments. Each of these has a specific responsibility and specific duties, and maintaining balance

BETWEEN THEM IS ESSENTIAL FOR THE EFFECTIVE OPERATION OF THE PROGRAM.

ALTHOUGH EARTHQUAKE HAZARDS ARE MOST FREQUENTLY ASSOCIATED WITH CALIFORNIA, ALL OR PORTIONS OF 39 STATES, 70 MILLION PEOPLE ARE AT RISK. THE RISKS TO LIFE AND PROPERTY ARE AS GREAT NOW AS WHEN THE BILL WAS PASSED, AND THE NEED FOR A COORDINATED NATIONAL APPROACH IS EQUALLY GREAT.

THE INFREQUENCY OF CATASTROPHIC EVENTS, SUCH AS EARTHQUAKES, TENDS TO PRODUCE AN ATTITUDE OF NEGLECT. IT IS THE RESPONSIBILITY OF CONGRESS TO INSURE THAT NEGLECT OF THIS PARTICULAR LEGISLATION DOES NOT OCCUR. INVESTMENT IN MEASURES TO MITIGATE THE EFFECTS OF EARTHQUAKES CAN BRING GREAT SAVINGS IN LIVES, IN RECOVERY, AND IN COSTS OF REPAIR LATER ON.

I WELCOME YOU TO THE HEARING TODAY.

Mr. **Walgren**. Also at this point in the hearing, I want to indicate that Mr. Boehlert's opening statement will be received for the record.

[The prepared opening statement of Mr. Boehlert follows:]

HONORABLE SHERWOOD BOEHLERT (R-NY)

OPENING STATEMENT

EARTHQUAKE HAZARDS REDUCTION ACT REAUTHORIZATION

MARCH 10, 1987

MR. CHAIRMAN:

OF ALL THE NATURAL PHENOMENA THAT HAVE PLAGUED MANKIND, EARTHQUAKES REMAIN AMONG THE MOST MYSTERIOUS. THEIR ORIGINS ARE NOT ALWAYS CLEAR, OUR ABILITY TO PREDICT THEM IS PRIMITIVE, AT BEST; AND OUR CAPACITY TO PREPARE FOR THEM IS INADEQUATE.

I'M EAGER TO HEAR TODAY JUST HOW MUCH PROGRESS WE HAVE MADE IN FILLING THOSE GAPS. PROGRESS WILL REQUIRE TWO SIMULTANEOUS THRUSTS -- RESEARCH AND APPLICATION.

WE SOMETIMES HEAR COMPLAINTS THAT THE PROGRAM IS SKEWED IN FAVOR OF RESEARCH. THE FACT IS WE NEED MORE RESEARCH AND MORE APPLICATION. ALL THE EARTHQUAKE PLANNING AND CODES ARE GOING TO BE OF LIMITED VALUE, IF OUR SCIENCE IS RUDIMENTARY. AND OBVIOUSLY, THE SCIENCE WILL BE OF LITTLE VALUE IF ITS LESSONS ARE NOT APPLIED.

THE DEBATE OVER THE PROPER BALANCE BETWEEN RESEARCH AND APPLICATION IS A SIGN OF TENSION WITHIN THE EARTHQUAKE PROGRAM. GIVEN THE DIFFERENT MISSIONS OF THE PARTICIPATING AGENCIES AND ITS DIFFUSE STRUCTURE, THIS TENSION IS HARDLY SURPRISING. I HOPE THAT AFTER TODAY WE CAN FIND SOME MORE WAYS TO HARNESS THAT NATURAL TENSION FOR CREATIVE, CONSTRUCTIVE PURPOSES.

IN PARTICULAR, I WANT TO BE SURE ENOUGH ATTENTION IS BEING PAID TO THE EARTHQUAKE THREAT EAST OF THE ROCKIES. THE AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES REPORTS THERE IS A 100 PERCENT PROBABILITY OF A SIGNIFICANT EARTHQUAKE IN THE EAST IN THE NEXT 25 YEARS.

WITH THE SHIFT OF RESPONSIBILITY FOR EASTERN MONITORING FROM THE NUCLEAR REGULATORY COMMISSION TO THE U.S. GEOLOGICAL SURVEY, FEMA'S PROPOSED COST-SHARING REQUIREMENTS, AND THE NEW EARTHQUAKE ENGINEERING RESEARCH CENTER IN MY HOME STATE, THE STUDY OF EASTERN QUAKES SEEMS TO BE IN A STATE OF FLUX. THE RISK OF EASTERN QUAKES CANNOT BE IGNORED.

WHEN IT COMES TO THE STUDY OF EARTHQUAKES, KNOWLEDGE IS INDEED POWER -- POWER TO LIMIT DEATH AND DESTRUCTION. WE MUST CONTINUE TO MAKE PROGRESS TOWARD THAT GOAL.

THANK YOU.

Mr. **Walgren**. I want to welcome the witnesses to this hearing today and thank them for coming to participate in these proceedings. We have with us David McLoughlin who is the director of State and local programs and support with FEMA along with Doyle Frederick, the associate director of the U.S. Geological Survey. Mr. Frederick as I understand is accompanied by John Filson who is focused on the Office of Earthquakes, Volcanos and Engineering and that is for the Geological Survey.

Also on this panel is Dr. Nam Suh, the director of the directorate for engineering at NSF accompanied by James Hays, the division director of Earth Sciences and Geosciences at the National Science Foundation.

We also have John W. Lyons, we really stacked you up on this panel and Dr. Lyons as many of you know is the director of the National Engineering Laboratory at the Bureau of Standards, accompanied by Richard Wright, director of the Center for Building Technology, also at the Bureau. Welcome, Dr. Wright.

That is a large panel and we appreciate your being here to make a record and give us your views of what the last year's effort has contributed to the national interest in this area and what we should be doing in the next year.

Let's go with the statements in the order that you were introduced and as you know, written statements will be made part of the record and I would encourage you to summarize and underscore the points that are best made in a hearing process like this and then when the written is taken together with the transcript of the verbal testimony, certainly our attention will be directed to the right issues.

So with that, let me start with Mr. McLoughlin.

STATEMENTS OF DAVE McLOUGHLIN, DEPUTY ASSOCIATE DIRECTOR, STATE AND LOCAL PROGRAMS AND SUPPORT, FEDERAL EMERGENCY MANAGEMENT AGENCY; DOYLE G. FREDERICK, ASSOCIATE DIRECTOR, U.S. GEOLOGICAL SURVEY; ACCOMPANIED BY DR. JOHN R. FILSON, CHIEF, OFFICE OF EARTHQUAKES, VOLCANOS AND ENGINEERING, U.S. GEOLOGICAL SURVEY; DR. NAM P. SUH, ASSISTANT, DIRECTOR FOR THE DIRECTORATE FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION; DR. JAMES F. HAYS, DIVISION DIRECTOR, DIVISION OF EARTH SCIENCES, GEOSCIENCES DIRECTORATE, NATIONAL SCIENCE FOUNDATION; AND DR. JOHN W. LYONS, DIRECTOR, NATIONAL ENGINEERING LABORATORY, NATIONAL BUREAU OF STANDARDS, ACCOMPANIED BY DR. RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY, NATIONAL BUREAU OF STANDARDS

Mr. **McLoughlin**. Thank you, Mr. Chairman and I will try to limit my remarks to about five, six or seven minutes.

I am pleased to appear before this subcommittee to support the reauthorization of the Earthquake Hazards Reduction Act. FEMA as designated lead agency has forwarded a request for a two year reauthorization of the National Earthquake Hazards Reduction Program.

This request includes an authorization of funding for the four principal agencies, FEMA, USGS, NSF and the National Bureau of Standards. The total requested in FY 1988 is $67,078,000.00 and in FY 1989, $71, 626,000.00.

As you will hear in the testimony from the panel, significant progress has been made in reducing the potential risk to people and property posed by earthquakes but much still remains to be done.

Mr. Chairman, my written statement includes a brief review of the legislative history of the program to help put into perspective FEMA's charge under the act. In the interest of time, I will defer my comments on details included in the written testimony.

Our Earthquake Program has six program elements and I will highlight the most important accomplishments, initiatives and FY 1988 activities in each area.

The focus of our leadership responsibilities is threefold, first, to provide for the coordination of the National Earthquake Program which is accomplished through a comprehensive system of committees addressing overall policy and planning as well as coordination of specific federal activities.

Second is to provide for comprehensive reporting to the Congress on the status of Earthquake Program activities undertaken by the federal agencies doing earthquake related work.

Third, assess and revise the program plan. This area will receive heightened attention in fiscal year 1987 and 1988 as we address pertinent issues relative to the progress and future direction of the program. To accomplish this we have initiated two actions, revision of the current five year plan and a survey of the first ten years of the program.

The revised five year plan must be submitted to Congress by September 1988. To meet this objective, FEMA has established an expert review committee composed of 15 non-federal members nominated by the four agencies represented here.

They represent the broad spectrum of public and private groups which comprise the earthquake community. We believe this committee is the appropriate mechanism for soliciting outside expertise as encouraged by the Congress.

Recognizing that it has been ten years since the passage of the Earthquake Hazards Reduction Act, we have initiated a contract to survey the results of the first ten years. This survey will provide baseline data on the program and it should be of benefit to all of the agencies and the Congress.

Our second area of program activities is seismic design and construction. FEMA is the primary agency working to translate research in this area into the tools for implementation. Further, we are the primary agency working with State and local officials to assist them in using these tools to implement and adopt seismic design standards and provisions.

In new buildings, the Building Seismic Safety Council, with FEMA support, is engaged in a nationwide campaign to disseminate and provide technical assistance in the application of the recommended provisions for the development of seismic regulations for new buildings.

These provisions published in 1985 provide the technical base for development of seismic resistant codes by State and local officials. In addition, the BSSC is updating these provisions to incorporate new data and the results of the emerging Mexico City research.

Existing building represent the greatest potential for loss in an earthquake. To mitigate this threat, FEMA will complete by FY 1989 a set of "How To" books to assess the existing hazardous building problem, set priorities and develop long-term mitigation programs based on the current state of the art.

In the area of lifelines, FEMA has developed a plan for addressing the seismic hazard of life lines in both the Federal and nonfederal sectors.

To demonstrate federal leadership, the agencies have developed an executive order on seismic resistant design and construction for Federal buildings.

As I noted earlier, State and local governments have the primary responsibility for the protection of life and property. They must undertake activities to identify the risk and to protect the life and property of their constituents.

FEMA provides financial support for this effort in 12 identified high risk areas which encompass 19 States and territories.

In these areas, FEMA supports a broad spectrum of activities which varies with the level of seismic risk, the level of earthquake awareness and the availability of mitigation tools.

California clearly represents the most aware and advanced state in earthquake hazards reduction activities and has become a model for other State and local efforts. The planning process and materials developed by California have been widely disseminated and can be used as a starting point for other State and local projects.

In the central U.S., under the leadership of the Central U.S. Earthquake Consortium, seven States have joined to promote implementation of regional solutions for earthquake along the New Madrid fault.

The state of Kentucky, a member of CUSEC, with the aggressive support of the Governor has launched a very aggressive program of earthquake hazard reduction activities. Through the workings of their State Seismic Council, they developed a medical response plan which has since been adopted by all seven CUSEC States.

In the east, there is an increasing awareness by state and local officials that a serious earthquake could occur. Massachusetts has been instrumental in organizing the New England Seismic Advisory Council and is in the process of developing an earthquake loss estimation study.

A major change will be made in FEMA's approach to state and local programs in fiscal year 1988. We will require the States to cost share funding of their earthquake activities. Cost sharing of these activities will help promote a State commitment as well as institutionalize these activities.

In Federal Response Planning, the Plan has been completed and is currently being signed by the 25 agencies with specific responsibilities as designated in the plan.

In education, FEMA is playing a primary role in initiating activities to educate the public on the effects of earthquakes and how they can reduce their effects.

Of note this year is the Guidebook for Developing a School Earthquake Safety Program, work at the Children's Television Workshop to prepare kits to help children deal with earthquakes, an active program of development and deployment of earthquake related training courses and a series of seminars which will look at how research results do or don't get applied.

Having provided an overview of what FEMA is doing, I would like to take a moment to address the issue raised in your letter, Mr. Chairman, concerning the division of activities under the Earthquake Program agencies.

We believe there is a need for continuation of strong research programs to provide new and improved research data to be used as a sound technical base for all earthquake hazards reduction activities.

We do, however, believe that a portion of this research should be specifically targeted for applied or translated research. Specifically, this research should be targeted to solve specific problems, such as existing building retrofit and the research should result in a usable product such as a handbook on How to Retrofit.

Currently only a small portion of the National Earthquake Hazard Reduction Program budget is devoted to this type of research. We believe that applied research is critical for addressing the most pressing life safety problems associated with earthquake hazards reduction.

In conclusion, we firmly believe the success of the National Earthquake Hazards Reduction Program will depend upon how well we at the Federal level have assisted State and local governments and the private sector in earthquake hazard reduction programs.

Thank you for the opportunity to address the panel today, Mr. Chairman, and we are glad to respond to questions.

[The prepared statement of Mr. McLoughlin follows:]

STATEMENT OF
MR. DAVE MCLOUGHLIN, DEPUTY ASSOCIATE DIRECTOR
STATE AND LOCAL PROGRAMS AND SUPPORT
FEDERAL EMERGENCY MANAGEMENT AGENCY
BEFORE THE
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
MARCH 10,1987

I am pleased to appear before this session of the House Committee on Science, Space and Technology, Subcommittee on Science, Research and Technology to support the reauthorization of the Earthquake Hazards Reduction Act of 1977, as amended. The Federal Emergency Management Agency (FEMA), as designated lead agency, has forwarded for your consideration a request for two year reauthorization of the National Earthquake Hazards Reduction Program (NEHRP). This request includes authorization of funding for the four principal agencies of the NEHRP: FEMA, United States Geological Survey (USGS), National Science Foundation (NSF) and National Bureau of Standards (NBS) for Fiscal Years 1988 and 1989. The total sum requested in FY 88 is $67,078,000 and $71,626,000 in FY 89. This request is comparable to the sums authorized in Fiscal Year 1987. As you will hear from the testimony of my colleagues and myself, significant progress has been made in reducing the potential risk to people and property posed by earthquakes. However, much still remains to be done and reauthorization of the Program is essential for the continuation of this critical work.

My remarks today will include a statement on the objectives of the NEHRP and a brief review of the legislative history of the NEHRP. This will help put into perspective my discussion of FEMA's activities undertaken to fulfill our charge under the Earthquake Hazards Reduction Act.

The Earthquake Hazards Reduction Act of 1977 (P.L. 95-124), as amended, has as its purpose the reduction of the risks to life and property in the United States from future earthquakes through the establishment and maintenance of an effective earthquake hazards reduction program. The objectives of the NEHRP include earthquake hazard identification and vulnerability analysis, seismic design and construction standards, earthquake prediction, preparedness and response planning, public education, fundamental and applied research studies and mitigation.

In creating the NEHRP, Congress brought together the earthquake hazard research programs already underway of the USGS and NSF. The original Act called for the designation of a lead agency to provide overall Program coordination, direction and management. As this legislation was being developed, it was determined that the lead agency role could be best fulfilled by an implementing agency. It was further recognized that the results of the earthquake related research must be applied and implemented so that the goal of reducing earthquake hazards on a national level could be achieved. Following the creation of FEMA in 1979, the Act was amended in 1980 to designate FEMA as the lead agency with the primary responsibility to plan and coordinate the NEHRP. In addition, FEMA was charged with undertaking activities that, when carried out, would effect earthquake hazards reduction. This legislative assignment to FEMA was made because FEMA's overall mission is to coordinate Federal emergency management activities (preparedness, response, recovery, and mitigation) for all types of disasters - natural and manmade - and to provide technical and financial assistance to State and local governments in carrying out their emergency management programs. Also, FEMA, through its civil defense and other existing preparedness programs, already had developed the emergency management infrastructure which could be used to complement and support implementation of earthquake hazards reduction efforts.

With the addition of FEMA as a principal agency, the NEHRP changed from a research program to an integrated and comprehensive Federal program for earthquake hazards reduction. It was a recognition by Congress that once the technical or research base was developed, State and local governments must play a primary role in earthquake hazards reduction since they ultimately bear the responsibility for the protection of life and property. It is for this reason that FEMA maintains a unique role among the principal agencies as being the primary agency responsible for translating the research programs of the other agencies into effective earthquake hazard reduction measures at the State and local level.

With this as background, FEMA developed a multi-faceted approach to its responsibilities under the NEHRP.

The FEMA Earthquake Program has 6 program elements:

(1) Program Leadership
(2) Seismic Design and Construction Standards
(3) State and Local Hazards Reduction
(4) Federal Response Planning
(5) Multi-hazard Planning
(6) Earthquake Education and Information Transfer

This testimony will highlight accomplishments, ongoing activities and Fiscal Year 88 activities in each area but will focus on the first three areas where the majority of FEMA's financial and staff resources are expended.

Program Leadership

As noted earlier, in creating the NEHRP Congress intended to provide a coherent program that would work in a rationale way to reduce the potential damage from earthquakes. The diversity of agencies, issues and groups involved in earthquake hazards reduction required that a lead agency be designated to coordinate these diverse efforts, recommend complementary efforts and to assure dissemination and implementation of scientific knowledge in the appropriate public and private sectors.

The focus or goal of FEMA's leadership responsibilities is threefold:

(1) Provide for effective coordination of the NEHRP;
(2) Provide for comprehensive reporting to Congress on the status of the NEHRP; and
(3) Provide for review, analysis, assessment and revision of the NEHRP as necessary.

Coordination of the NEHRP is accomplished through a comprehensive system of committees. These are the Policy Coordinating Group (PCG), the Interagency Coordination Committee (ICC), the Federal Response Planning Subcommittee of the ICC, and the Interagency Coordination Committee on Seismic Safety in Construction (ICSSC), also a subcommittee of the ICC. The ICC is composed of program-manager level representatives of the four principal agencies as well as other departmental agencies involved in earthquake work. Regular meetings of the ICC provide for discussion of program issues and activities and insures overall program coordnation. When issues can not be resolved at the ICC, they are forwarded to the PCG which is composed of senior-policy level officials of the four principal agencies. This Group provides guidance on program policy, budget and planning issues. The ICSSC is chaired by NBS but FEMA provides the funding for the Secretariate of this Committee. The purpose of the ICSSC is to develop and promote a strong seismic design and construction mitigation program throughout the Federal community. The importance of a strong Federal program was evidenced in the failure of government buildings in the 1985 Mexico City earthquake.

Although continued improvement has been recognized in all committees, there has been two accomplishments of note. The Federal Response Planning subcommittee approved and forwarded to the 25 member agencies for signature, the Plan for Federal Response to a Catastrophic Earthquake. Secondly, the ICSSC developed a proposed Executive Order on Seismic Safety for Federal Buildings.

The second lead agency focus is submittal to Congress of the Annual Report on the NEHRP as required under Section 6 of the legislation.

FEMA's submittal of the Annual Report provides to Congress a comprehensive report of each Fiscal Year activities undertaken by the four principal agencies and the other Federal agencies doing earthquake related work. This report is a considerable undertaking and requires the cooperation of all agencies involved. The FY 86 report was sent to all members of the Committee in February and it is commended to your attention. Over the past three years, FEMA has become justifiably proud of the content and timely delivery of this document.

The final area of focus as lead agency is the review, assessment and revision of the NEHRP. This particular area is receiving heightened attention right now. FEMA believes it is a lead agency responsibility to raise and address pertinent issues relative to all aspects of the NEHRP. We also believe it is important to review the progress of the Program, to look toward future directions and to make or recommend changes as necessary. To accomplish these activities, FEMA has initiated two actions, revision of the current NEHRP 5-Year Plan and a survey of the first ten years of the NEHRP.

As called for by the legislation, a revised NEHRP 5-Year Plan must be submitted to Congress by September 1988. To initiate the Plan revision process, FEMA, in conjunction with the other principal agencies, has established an Expert Review Committee. This Committee is composed of 15 non-Federal members nominated by each of the four agencies.

Each member was nominated because of his or her particular technical expertise. They also represent the broad spectrum of public and private groups which comprise the earthquake community.

Congress has consistently encouraged FEMA to seek outside expertise on the NEHRP and we feel this Committee is the appropriate mechanism for soliciting this expertise.

The Committee has been given four tasks to perform:

(1) to review the program structure of the current 5-Year Plan and recommend changes if necessary;

(2) to review the NEHRP program and identify program specific issues to be considered by the agencies over the next 5 years;

(3) to review the NEHRP and identify issues which impact the program as a whole which should be considered over the next 5 years; and

(4) to recommend options for resolving these issues.

The report of the Committee will be forwarded to the principal agencies for their consideration in revising the 5-Year Plan.

Concurrent with this process, FEMA, recognizing that it has been ten years since the passage of the Earthquake Hazards Reduction Act, has initiated a contract to survey the first ten years of the NEHRP. The intent of this survey is to provide baseline data on the Program and how it has functioned. This is the first such review undertaken by FEMA and it should be of benefit o all of the agencies as they begin to revised the 5-Year Plan.

Seismic Design and Construction Standards

As was so graphically illustrated in Mexico City, the partial failure or the collapse of buildings poses the greatest potential threat to life and property from an earthquake. The importance of improved seismic design and construction standards to reducing the earthquake hazard can not be underestimated. Because of this significant payoff in hazard reduction, FEMA allocates approximately $1.5 million of its earthquake appropriations to this area. The focus of FEMA's work is in three areas; new buildings, existing buildings and lifelines for two distinct constituencies, the Federal and Non-Federal communities. The Federal efforts will be briefly discussed and emphasis will be placed on the non-Federal sector.

Under the auspices of the ICSSC, a proposed Executive Order on seismic resistant design for Federal buildings was developed. The ICSSC has also developed Federal Guidelines for seismic resistant design for new buildings. Currently, in the area of existing Federal buildings, the ICSSC is in the process of reviewing proposed Federal Guidelines for seismic resistant design for existing buildings. Under lifelines, a Plan is currently being developed which will address both Federal and non-Federal sectors. Under this Plan, actions specifically applicable to the safety of Federal buildings will be recommended and implementation activities identified.

State and local governments have the primary responsibility for the protection of life and property in the event of an earthquake. It is in the area of non-Federal seismic design and construction where FEMA plays a unique role among the principal agencies. In the seismic design and construction area, FEMA is the primary agency working to translate research into tools for implementation. Further, FEMA is the primary agency working with State and local officials to assist them in using these tools to implement and adopt seismic design standards and provisions. The focus of FEMA's program for accomplishing this is through the development of practical "how to" handbooks and guidelines and the provision of technical assistance to State and local officials, buildings and code officials and private design and construction professionals for new buildings, existing buildings and lifelines.

In 1985, FEMA published the NEHRP Recommended Provisions the Development of Seismic Regulations for New Buildings for use by State, local and private sector groups. This was the first such national document developed through a consensus process. This process, employed by the Building Seismic Safety Commission, included over 57 research, construction, design, and code organizations. These provisions have been recognized in several national engineering forums as a significant accomplishment and as the potential basis for a single uniform national model seismic building standard. FEMA's current efforts are focused on a campaign of widespread dissemination and technical assistance in the application of these Provisions. The dissemination efforts are particularly targeted to nationwide developers and owners, elementary and secondary school officials, health care and hotel-motel developers. FEMA is also in the process of updating the Provisions to incorporate new data and the results of the research on building performance from Mexico City. The update is expected to be completed in FY 88.

Existing buildings represent the greatest potential loss of life in an earthquake. Mitigating the threat from existing buildings is one of the biggest challenges faced by States, locals and the private sector.

The basis for addressing this challenge is a Plan developed for FEMA by the Applied Technology Council, Building Seismic Safety Council and Earthquake Engineering Research Institute. The Plan development process involved a large number of organizations and specialists in earthquake engineering, public policy and other disciplines concerned with earthquake hazardous buildings. The Plan included research, modeling, development of engineering techniques and development of practical use manuals. The Plan identified and made recommendations for activities to be undertaken by the NEHRP agencies. Currently, FEMA has made a major commitment to implementing the recommendations called for in the Plan. Also, NSF, through its unsolicited proposal process, is funding research related to the existing building problem.

FEMA has undertaken an active program to fund the development of "how to" handbooks for States, locals and the private sector to assess their existing hazardous building problem, set priorities and develop long-term mitigation programs based on the current state of the art.

The following handbooks, initiated in FY 86 and FY 87 and to be completed in FY 88 and FY 89, will provide technical guidance to building code officials, State and local engineers, policy makers and design professionals on:

(1) how to assess the existing building hazard in a community

(2) how to evaluate the degree of seismic hazard for major types of buildings

(3) how to set priorities for rehabilitation among hazardous buildings

(4) how to estimate costs for rehabilitation of major types of buildings

(5) providing data on the typical costs of specific rehabilitation techniques

When completed and disseminated, these handbooks begin to provide the tools necessary for a community or State to implement earthquake hazards reduction programs in existing buildings and to reduce their potential losses from existing buildings should an earthquake occur.

The last element of FEMA's seismic design program is lifelines. FEMA has just initiated activities in this area. The potential scope of the lifeline problem, especially relative to potential property and economic loss should a major earthquake occur, is staggering. To begin to address this complex, diverse and critical area, FEMA adopted an approach similar to that for existing buildings. Currently under development is a Plan that will provide a roadmap for addressing the seismic safety of lifelines for both the Federal and Non-Federal sectors in the following categories: communication, electric power, water and sewer, transportation and gas and oil.

This Plan will be submitted to FEMA in April. We already know that significant research still needs to be done to provide a sound technical base for lifeline mitigation techniques. We believe that to be effective, this research must be focused toward eventual application in order to facilitate translation of this research into implementation tools. FEMA hopes to work with NSF, possibly through the new Center in Buffalo, to support the targeted research needs to be identified in the Plan.

State and Local Hazards Reduction

As noted earlier, States and local governments have the primary responsibility for the protection of life and property. While the greatest potential for reduction of risk lies in seismic design, there are other activities that must be undertaken by State and local jurisdictions to identify the risk and to protect the life and property of their constituents. These activities comprise FEMA's State and local hazards reduction program element. FEMA allocates to this element approximately $1.5 million of its appropriated earthquake funds.

Because of the overall mission of FEMA as an agency charged to work with State and locals to prepare for, respond to and mitigate natural and manmade hazards, the earthquake program benefits from the existing emergency management structure supported by other FEMA programs.

The preparedness, response and recovery infrastructure supported by FEMA's Civil Defense Program complements and enhances FEMA's earthquake preparedness efforts at the State and local level. The recent Presidential National Security Decision Directive on Civil Defense reinforces the supportive links between natural and manmade hazards, particularly as it relates to the impact of natural hazards on national security.

Of the principal agencies, FEMA is the primary agency working with State and local officials to implement earthquake hazard reduction programs. Most often the base for these activities is found in the research programs of the USGS. FEMA is working with the USGS to more closely coordinate their program of regional hazards assessment with FEMA's State and local hazards reduction activities. FEMA currently supports programs in all 12 identified high risk areas which encompasses 19 States and territories. FEMA provides financial support for State and local programs which focus on:

hazard identification/vulnerability assessment
preparedness planning
response planning
mitigation planning
public awareness and education

Within the 12 risk areas, a broad spectrum of activities are being undertaken. The scope of these activities varies with the level of seismic risk data, level of earthquake awareness and availability of mitigation tools.

A cross-section of examples of the State and local earthquake hazards reduction activities follows.

California clearly represents the most aware and advanced State in earthquake hazards reduction activities. The Southern California Earthquake Preparedness Project (SCEPP) has become a model for other State and local efforts. The planning process and materials developed by SCEPP and its sister organization to the North, the Bay Area Earthquake Preparedness Project (BAREPP), have been widely disseminated and can be used as a starting point for other State and local projects. Part of the acknowledged success of these projects can be attributed to a heightened awareness on the part of State and local officials that a very real earthquake threat exists.

This awareness found its base in scientific research and actual earthquake occurrence. However, even within California, earthquake consciousness can sometimes lag. The joint earthquake planning project between Mexico and the US/San Diego has been revitalized as a result of the Mexico City earthquake and the recent research results on seismicity in the San Diego area. This project is the only such joint planning effort between Mexico and the U.S.

As we move east of California, State and local programs reflect an ever growing awareness of the potential impact of a major earthquake. In the Central U.S., under the leadership of the Central U.S. Earthquake Consortium (CUSEC), which is based in Illinois, seven States have joined to develop earthquake hazards reduction programs. A repeat of the 1811-1812 New Madrid earthquake would severely test the capability of any single State to respond, thus making inter-State mutual aid essential. CUSEC, which is funded by FEMA, is designed to promote implementation of regional solutions for earthquake hazards reduction.

The State of Kentucky, a member of CUSEC, with the support of the Governor has launched a very aggressive program of earthquake hazard reduction activities. Through the workings of their State Seismic Council, they developed a medical response plan which has since been adopted by all seven CUSEC States.

State and local activities in the east also reflect a recognition that an earthquake could happen there. The State of Massachusetts is in the process of developing an earthquake loss estimation study, one of the basic tools necessary to begin preparedness planning and all other earthquake hazard reduction efforts.

The State of New York has set up a State Seismic Advisory Committee as the first step in developing a State earthquake hazard reduction program. The National Earthquake Center at Buffalo, funded by NSF will bring further focus to the need for earthquake hazard reduction activity east of the Rockies.

This increasing State and local activity led FEMA to request that the National Academy of Sciences provide FEMA with recommendations on the best methodology for estimating earthquake vulnerability nationwide. Basically, FEMA asked, could a standard methodology for earthquake loss estimation be applied across the nation. The preliminary report of this Panel is due in June.

A major change will be made in FEMA's approach to State and local programs in FY 88. In FY 88, FEMA will require the States to cost share on a 50/50 basis funding of their earthquake activities. Earlier this year, FEMA had begun to explored the possibility of moving to a cost share program and had alerted the States to this possibility. FEMA concluded that State and local governments should pay the costs of these activities which they conduct and control. This is the same cost share that FEMA requires in its civil defense programs. Cost sharing of earthquake hazards reduction activities will help promote a State commitment as well as institutionalize these activities within the State and local governmental structure. A good example of this is California. The State of California has successfully cost-shared their earthquake hazard reduction activities with FEMA since 1980.

While we now have earthquake activities underway in all high risk areas, there are stumbling blocks which must be overcome. Public perception of earthquakes and the recognition of the need for personal preparedness must be improved. Among State and local officials, earthquake hazard reduction must compete with other priorities for scarce resources. More tools for implementing cost-effective earthquake hazard mitigation programs still need to be developed.

FEMA's remaining 3 earthquake program elements, Federal Response Planning, Multi-hazard Planning and Earthquake Education and Information Transfer, and staff for FEMA's earthquake program account for the remaining appropriated earthquake funds.

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Federal Response Planning

Section 5 of the Earthquake Hazards Reduction Act, as amended, requires that the Director develop a plan for the Federal Government's response to a catastrophic earthquake. It was acknowledged that such a plan would be necessary because any catastrophic earthquake would overwhelm the capabilities and resources of State and local governments. Under the aegis of the Subcommittee on Federal Response Planning of the ICC, FEMA and 24 other Federal agencies developed the Plan for Federal Response to a Catastrophic Earthquake. This Plan represents a milestone of significantly increased Federal Government preparedness to respond to a major earthquake in any identified high risk, high population seismic area.

The Plan establishes the policies, concept of operations and specific responsibilities upon which a Federal response would be carried out. Regional interagency planning is being initiated in FY 87 for all high risk areas to develop Federal/State coordination mechanisms, procedures, and administrative and logistical requirements that will make the Federal response possible.

The Federal Government will be participating in a State of California sponsored three-day exercise named RESPONSE 87, which will be based on a simulated catastrophic earthquake on the southern San Andreas Fault in October 1987.

Multi-Hazard Planning

FEMA's multi-hazard program element has been concentrating on those hazards which are associated with earthquakes. A project with the State of Colorado has been initiated to develop a model State program for landslide hazard reduction. The model program and a "how to" handbook will be distributed to the States in FY 88.

Earthquake Education and Information Transfer

Although the Chile and Mexico City earthquakes heightened public awareness and stimulated media interest in earthquakes, the level of public awareness and knowledge about the causes and effects of earthquakes is still in question. FEMA's last program element, earthquake education and information transfer is designed to address this problem. The focus of FEMA's program is the development of educational materials and courses for the general public and specific group audiences.

FEMA is playing a primary role in initiating activities to educate and prepare the public on the effects of earthquakes and how they can work to reduce or minimize those effects.

Of significance, this year FEMA published a Guidebook for Developing a School Earthquake Safety Program. The response to this publication has been overwhelming. At the request of the State of California, FEMA has provided copies for distribution to each public and private school within the State. To date, over 25,000 copies have been distributed to States, localities and foreign governments.

Under the Natural Hazards Project funded by FEMA, the Children's Television Workshop, the Seasame Street people, have begun to prepare "Big Bird Get Ready" kits for earthquakes. These materials will address children in 3 age groups: pre-school, 6-8 and 9-11, with special messages and materials designed for each. FEMA expects these materials will be ready for testing in late FY 88. FEMA then plans a program of dissemination and training in the use of the materials for public and private groups.

FEMA also has an active program of development and deployment of earthquake related training courses for specific audiences. These courses are offered at FEMA's National Emergency Training Center (NETC) in Emmitsburg, Maryland, as well as in the field. Currently available are: Earthquake Mitigation for Utility Lifelines, designed for city and county public works directors and engineers; Non-Structural Mitigation for Hospitals; Earthquake and Fire Hazards Mitigation for High Rise Buildings and a new course in how to interpret and apply the NEHRP Recommended Provisions for New Buildings.

In FY 88, FEMA will complete revision of its multi-year earthquake education plan which will define the scope of FEMA's earthquake training program for FY 89-93. This Plan will be incorporated into the revision of the NEHRP 5-Year Plan.

Other activities of interest to the Committee are: continuation of the seismic design workshops funded by FEMA through the American Institute of Architects/Association of Collegiate Schools of Architecture. Consistent with FEMA's philosophy that seismic design and construction represents the highest potential for earthquake hazard reduction, these workshops are intended to stimulate interest and use of seismic considerations, including the NEHRP Provisions, among the private sector design professionals. In FY 87 and FY 88, FEMA will be convening workshops in the States of Missouri, Massachusetts, and a state-of-the-art workshop will be held in San Francisco, California. Jointly funded by the State of California, this workshop will incorporate the results of the emerging research from the Mexico City earthquake.

Finally, in this area, FEMA in conjunction with the USGS and NSF, will be holding a series of seminars this year which will look at how research results get applied and how successful have we, at the Federal level, been in promoting application of research at the State and local level. These will have a regional orientation and be held in San Diego, California; Denver, Colorado; and Knoxville, Tennessee.

The rare occurrence of noticeable earthquakes in the U.S. continue to make public education a challenge. FEMA believes the scientific facts exist to argue that earthquakes and the potential for damaging earthquakes are a nation-wide problem. Only through continued education efforts like those previously mentioned can we hope to reduce the effects of this lack of public recognition.

In closing, FEMA would like to emphasize that much progress has been made under the NEHRP to reduce the potential loss of life and property from earthquakes, but there is still much left to be done. Congressman Walgren's letter requested we address the appropriateness of the division of activities under the NEHRP. We believe there is a need for a continuation of the strong research programs of NEHRP to provide new and improved scientific data as a sound technical base for all other earthquake hazards reduction activities. But there is also a need for a portion of this research to be directed or targeted research to support implementation of the program, especially in the area of seismic design and construction.

FEMA has a unique role in accomplishing the goals and objectives of the NEHRP. Not only as a lead agency, but more critically as the primary agency working with State and local governments to translate research into actual implementation of earthquake hazard reduction actions. FEMA firmly believes the success of the NEHRP will depend on how well we, at the Federal level, have assisted States and local governments and the private sector in effecting earthquake hazard reduction programs.

Mr. **Boehlert** [presiding]. Thank you, Mr. McLoughlin. Mr. Frederick.

Mr. **Frederick**. Thank you, Mr. Chairman. I am pleased to appear before this subcommittee to support the reauthorization of the National Earthquake Hazards Reduction Program and to comment briefly on Geological Survey activities.

I am as mentioned earlier accompanied by John Filson who heads our Earthquake Program in the Geological Survey.

In my statement, I would like to address the issues raised in the opening comments having to do with overall progress during the last ten years, budget and program related activities and the relationship with the State and local officials, and coordination amongst the Federal agencies.

During the last ten years as mentioned by Mr. McLoughlin there has been considerable progress in the understanding of earthquake hazards, in identifying and assessing the potential for destruction throughout the country and in developing earthquake prediction systems and also, I might add, in putting the results of our work into the hands of those that must make the policy and management decisions.

Some examples of the progress from the point of view of the Geological Survey include the development of techniques for estimating long-term earthquake potential, development and publication of a national scale seismic risk map, completion of regional earthquake hazards assessment and carrying the earthquake, prediction research into the field in a full-scale operational test.

The Geological Survey's role in this, we believe is to begin with some fundamental research but research specifically directed to the applications as mentioned earlier and in just a few minutes I want to comment on some specific examples of that type of research.

The Geological Survey, as the committee knows, is responsible for doing the research and for publishing the results of that research. We are working actively with the Federal agencies and those at the State and local level.

You also are aware that we are specifically given the responsibility for issuing hazards alerts; and that aspect does drive our program considerably.

Our program is divided into five components—regional earthquake monitoring and earthquake potential estimation, earthquake prediction research, regional earthquake hazards assessments, distribution of earthquake data and information and engineering seismology.

On the budget issue, you specifically in your invitation asked us to comment on the Geological Survey budget. For fiscal year 1988, we do find it necessary to reduce our work in support of the earthquake program to reach overall budget targets.

The budget reduction for fiscal year 1988 will be about four million dollars from the 1988 base. This will have impact on the regional seismic networks which will be reduced and we intend to reduce those that we think are of a lower priority. We will also scale back some of our research investigation activities.

Generally though, our fiscal year 1988 program is about $32 million dollars; and we consider that to be reasonable to meet our responsibilities in working toward the goals of the Earthquake Hazards Reduction Program, particularly in view of the tight budget situation.

Now turning to the issue of program balance, we too agree that it is important to continue fundamental research in understanding the earthquake problems, to develop better prediction strategies and also to be able to tell those that are responsible for implementation when something is likely to occur.

We do agree, however, that a strong research program ought to be focused on reducing earthquake hazards for the country and we have looked and continue to look at our program in that regard.

Specifically, we are involved in regional earthquake hazards assessments and we have just finished a three-year program in the Wasatch Front of Utah; and that area includes the cities of Provo, Salt Lake and Ogden.

You will hear, I believe a little later on, from Don Mabey, the State Geologist's Office in Utah, and Don can give you some more details on that. We think that is a very successful program that has gone quite far in identifying hazards for the area.

The second example is the Parkfield earthquake experiment. Parkfield is a small town in central California along the San Andreas fault. This area was picked for a couple of reasons. One is that we are fairly confident that there will be another magnitude-six earthquake in the reasonably near future.

Statistics and other scientific evidence have shown that those events occur on the average of about every 22 years.

The objective of this program is to put into place scientific monitoring equipment, cooperative arrangements with the State and local agencies for response to an alert system and for looking specifically at pre-monitory events that we might see and that might have applications to other parts of the country.

A third area of applications has to do with the results that we have developed. As you are probably aware, we have published hundreds of reports over the last several years and we understand that the publishing of those reports is not enough.

So we, together with FEMA and again State and local organizations, have conducted a series of 20 regional conferences or workshops from Alaska to Puerto Rico-Virgin Islands and from New York to California, on earthquake problems within these regions. These workshops, we believe, have been very effective in taking the results and providing the information that is usable to the folks that again have to use that data and respond.

These, Mr. Chairman, are just a few examples of how we are working with others, the Federal agencies and the State and local agencies, in providing the results of our research to broad applications throughout the country.

I thank you for the opportunity to be here and will be pleased also to answer questions that you may have.

[The prepared statement of Mr. Frederick follows:]

Statement of Mr. Doyle G. Frederick, Associate Director
U.S. Geological Survey, Department of the Interior
before the
Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
of the
House of Representatives
March 10, 1987

Mr. Chairman, I am pleased to appear before this subcommittee to support the reauthorization of the National Earthquake Hazards Reduction Program and to respond to your questions regarding the activities of the United States Geological Survey (USGS) under this program. This fiscal year is the tenth year we have participated in the program, and during the year we shall spend nearly $34 million on work directed towards its goals.

During the past 10 years, we have made considerable progress in the basic understanding of earthquake phenomena, in identifying and assessing the earthquake hazards of the country, in the development of earthquake prediction systems, and in pursuing procedures to put the results of our work into practical application. A list of the salient examples of our work during the past 10 years would include:

o Development of techniques for estimating the long-term earthquake potential of a fault.

- o Development and publication of national scale seismic risk maps that show the upper limit of the severity of ground shaking to be expected in 50-, 100-, and 250-year time periods.
- o Completion of regional earthquake hazards assessments in southern California and Utah.
- o Carrying earthquake prediction from a field of basic research to a full-scale experiment.

Many other examples exist although time does not allow us to cite them this morning.

Our role within the program during the past 10 years can generally be described by the terms "applied research." The USGS is primarily a scientific bureau engaged in geological and hydrological research, natural resource assessments, the development and application of mapping techniques, and the publication of maps and reports based on our work. Within the program our role has been to support research with a clear link to reducing earthquake hazards, to publish and make known the results of this research, and to work actively with State and local officials in the application of these results. We have borne the responsibility of issuing statements on earthquake hazards, both long and short term, when we judged it was appropriate. We have provided scientific leadership in those areas that we felt needed stimulation or direction. Thus, we are comfortable with our role of bridging the gap between pure research and practical application. We feel this role is appropriate given our overall mission and organizational capabilities.

Specifically, our program is cast into five major elements: regional earthquake monitoring and earthquake potential estimation, earthquake prediction research, regional earthquake hazards assessments, distribution of earthquake data and information, and engineering seismology.

In FY 1988, we find it necessary to reduce our work in support of the earthquake program to support higher priority programs while holding the overall budget about on level with FY 1987. The budget reduction will be $2.2 million from the FY 1987 level and $4 million from the FY 1988 base of this program. These reductions will be taken in those areas of the program which we judge to be of lower priority when measured as having less of a chance of eventual "pay-off" or eventual application. More specifically, regional seismographic networks will be reduced.

We feel that our remaining effort, over $32 million, is adequate to meet our responsibilities in working toward the goals of the Earthquake Hazards Reduction Program.

In your invitation, Mr. Chairman, you asked our views on any other issues which we might wish to bring to your attention.

During the past 2 years, there has been considerable discussion of program balance and whether the application of research results is commensurate with the level of research. I would like to elaborate on three examples, two of which were referred to briefly above, of our efforts to turn research into application.

The first example is in the regional earthquake hazards assessment element of our program. In 1984, we established a policy of focusing our earthquake hazards assessment work to provide more detailed analyses of earthquake problems and remedial actions for State and local officials. These analyses would be based on an intensive 3-year program in which new research and studies would be tailored to the needs of a particular region. The region chosen for the first effort was the so-called Wasatch Front of Utah, a region that includes the cities of Provo, Salt Lake, and Ogden. It was determined that chances of success of the effort would be increased if we could involve State and local government officials early on--make it their plan and give them a stake in the success of the plan. From the beginning of this project, we worked closely again with the Federal Emergency Management Agency, the Utah Geological and Mineral Survey, and the Utah Division of Comprehensive Emergency Management.

The results of the intensive scientific effort will be published in a major USGS report later this year. Although some implementation of these results and recommendations that arose from the 3-year effort have already taken place, we have decided to extend our support to the State for another 2 years (1987 - 1988) to enhance the local implementation effort. We understand an official of the Utah Geological and Mineral Survey has been called as a witness to this hearing, and his views on the impact and effectiveness of our efforts in his State should be of interest to you.

We have extended this program by beginning this year with a 3-year period of intensified studies of earthquake hazards in the Pacific Northwest. In December 1986 and again last week, we held another of a series of meetings with officials from Oregon and Washington to plan the field work that will begin this summer.

Another example of application of research results is in our Parkfield earthquake prediction experiment. Parkfield is a small town in central California along a section of the San Andreas fault that is judged to have a high probability of a moderate earthquake within the next few years. The high probability of an earthquake there offers the opportunity to test many scientific and technical results and procedural mechanisms stemming from earthquake prediction work thus far. The forecast of a magnitude 6 earthquake in the region was brought before and endorsed by the National and California Earthquake Prediction Evaluation Councils.

During the last 2 years, we have worked closely with the California Division of Mines and Geology and the Office of Emergency Services to install geophysical instruments in the region, to bring the data from this equipment to data centers in Menlo Park and Sacramento where it can be analyzed continuously, to develop criteria for various alert stages based on this analysis, and to establish procedures for issuing warnings to the public.

Thus, starting from scratch 10 years ago, we have carried earthquake prediction through, with all of its attendant scientific and social problems, to a fully operational test in the Parkfield region. The regions of this experiment and lessons learned from it may have much wider application.

Our final example of research implementation involves the dissemination of information. During the past 10 years, literally hundreds of scientific papers, reports, and maps have been published through our efforts in this program. In the early years, we recognized the need to get the results of our work into the hands of the practitioners: the engineers, the State and local officials, and the planners and emergency managers--where these results could be put to use. We further recognized that just mailing reports to these individuals would not ensure that our results became known, let alone put into use. During the past 10 years, we have conducted 20 regional conferences or workshops, from Alaska to Puerto Rico-Virgin Islands and from

New York to California, on earthquake problems within these regions and what may be done to mitigate these problems. Support for these workshops is often provided by the Federal Emergency Management Agency and other Federal and State agencies.

These, Mr. Chairman, are just a few examples of how we are carrying the results of research and technical work in a broad program through to implementation and application. With the reauthorization of this program, we shall continue to proceed aggressively in both research and application.

Thank you, Mr. Chairman. I would be happy to answer any questions.

Mr. BOEHLERT. Thank you very much, Mr. Frederick. We will proceed with Dr. Suh now.

Mr. SUH. Thank you, Mr. Chairman. I am pleased to have this opportunity to discuss the Foundation's Earthquake Hazard Mitigation Program. To allow as much time as possible for questions, I will give a brief overview of our program and with your permission, Mr. Chairman, I have a much longer and detailed written statement that I would like to have included in the record.

Mr. BOEHLERT. Without objection, so ordered.

Mr. SUH. We are requesting a 10.6-percent increase for the Earthquake Hazard Mitigation program in engineering for fiscal year 1988. This brings the total for the engineering part of earthquake research to $16.5 million compared to $15.1 million in fiscal year 1987.

The Foundation has both an earthquake engineering and geosciences research support program that are part of the nation's Earthquake Hazards Reduction Program.

My remarks will be on the earthquake engineering part of the NSF support effort. Dr. James Hays, Director of our Division of Earth Sciences, will discuss NSF's geosciences research support program. Our goal is to help find ways to reduce losses from earthquakes and to actually mitigate their effects.

I will first review our program activities and then discuss a number of the special activities we have undertaken this past year.

The National Science Foundation's earthquake engineering research is subdivided into four major areas including Siting and Geotechnical Systems; Structural Systems, Architectural and Mechanical Systems; and Earthquake Systems Integration.

The NSF engineering earthquake research support effort is aimed at, one, learning what happens when earthquake motions are transmitted to man-made structures, two, understanding the actual performance of structures and contents attached to these structures during an earthquake, three, finding ways to integrate and disseminate knowledge gained on earthquakes in a form that can be made readily available and efficiently used, and four, strengthening earthquake mitigation and preparedness planning.

Our Siting and Geotechnical Systems program supports research on strong ground motions; stability of geotechnical systems; tsunami systems engineering; and lifeline systems including roads, water systems and so forth.

This first slide shows a building that has failed as a result of liquefaction, that is, the loss of strength of the foundation materials due to strong ground motions.

We were fortunate to have had some strong ground motion equipment in place prior to the 1985 Mexican Earthquake. You can get some idea of the tremendous power of that quake from this slide which shows the record of the strong ground motions.

Structural Systems is another major research support category. Here, the research emphasis is on new and reliable design methodologies, computer simulation, including the use of artificial intelligence, damage assessment methodologies, and again, lifeline systems.

This badly damaged building helps illustrate the need for this sort of research thrust. Here we see a reinforced concrete building in which floor slabs have pancaked.

Our third major program is Architectural and Mechanical Systems, which includes research on non-structural elements.

An objective is to determine what needs to be done to retrofit existing structures to prevent their collapse during an earthquake. This is a broad-gauged effort that looks at the impact of earthquakes on glass and exterior cladding, elevators, building mechanical systems, power generation and transmission facilities and the like.

This slide, which shows some scaffolding on a church building, doesn't appear as being very unusual. But in this case, the church is being retrofitted to withstand earthquakes. This is in the Long Beach, California area. The methodologies that are being used, which include a sophisticated reinforcement system, were developed through NSF-supported research.

Something we have wanted to accomplish for many years is the implementation of what is called Base Isolation. That is a situation in which a structure is isolated from the earthquake ground motion through the use of elastomeric bearings. This slide shows a schematic of a bearing similar to the one that was used in California.

Our fourth area of research focus is Earthquake Systems Integration. I have already mentioned our effort to transfer research results to the user community. Another key aspect of this program is research on earthquake mitigation planning, earthquake preparedness planning and strategies for recovery and reconstruction.

So far, I have described our regular activities. Now let me describe a few of the special research efforts we have undertaken recently.

As you know, 1985 was a catastrophic year for earthquakes. There were tremendous losses of life and property suffered in Mexico and Chile from very strong earthquakes. We did our best to move research teams into these areas shortly after the earthquakes to gather important data on structure behavior and damage.

NSF is currently supporting 28 research projects in a cooperative effort with Mexico. The government of Mexico is supporting counterpart work and these projects are well integrated.

It is really a very productive cooperative research effort. I know you have seen pictures of the Mexican Earthquake before, but this one is worth viewing again.

We are supporting eight projects on the 1985 Chilean quakes. This research has been somewhat sobering for our investigators because their theories did not accurately predict the behavior of buildings during the earthquake.

For example, here is a building which apparently suffered foundation failure. However, on closer examination, this was actually a structural failure.

I want to emphasize that we are moving ahead very aggressively here at home with efforts that are aimed at pushing the state-of-the art forward in all aspects of Earthquake Hazard Mitigation.

We are very much concerned about the need to strengthen the systems approach to the study of earthquakes and their effects. As

I informed this committee in March 1985, NSF has recently and after a very intense competition, awarded a grant to the State University of New York at Buffalo for the establishment of an Earthquake Engineering Research Center.

The SUNY-Buffalo team is an outstanding group of experts in this field. Also, I should mention that the State of New York is a full partner in this venture and is providing more than one-half of the funds and other resources for the Center.

Earthquakes, of course, are a potential problem for all areas of the United States. It is interesting to note that the largest historic earthquake in the U.S. occurred in Missouri in 1811 and 1812. So in looking at earthquakes, it is important that we consider them in the context of a national program.

As I mentioned earlier, Mr. Chairman, the detailed statement we have provided for the record covers the breadth of our work and gives many examples of research accomplishment.

We believe that we have a very sound program for FY 1988. It is national in scope and vision and if pursued aggressively in future years, it should make a real difference in our ability to mitigate the damaging effects of earthquakes.

This concludes my statement, Mr. Chairman, and I will be happy to answer any questions.

[The prepared statement of Dr. Suh follows:]

National
Science
Foundation

STATEMENT OF

DR. NAM P. SUH

ASSISTANT DIRECTOR FOR ENGINEERING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

MARCH 10, 1987

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE

THE NATIONAL SCIENCE FOUNDATION'S EARTHQUAKE HAZARD MITIGATION (EHM) PROGRAM IN THE ENGINEERING DIRECTORATE AT NSF SUPPORTS FUNDAMENTAL RESEARCH IN ENGINEERING DIRECTED TOWARD MITIGATION OF THE EFFECTS OF EARTHQUAKES.

THE EHM PROGRAM IS A RESULTS-ORIENTED PROGRAM WHERE THE OVERALL GOAL IS TO STRENGTHEN THE EXISTING KNOWLEDGE BASE IN EARTHQUAKE ENGINEERING IN ORDER TO MINIMIZE THE LOSS OF LIFE AND RESOURCES DUE TO EARTHQUAKES.

THE EHM PROGRAM IS ORGANIZED TO PROVIDE PROPER PRINCIPAL AGENCY INPUT TO THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM AS DETAILED IN THE FIVE YEAR PLANNING DOCUMENT. THIS PLANNING DOCUMENT IS UPDATED PERIODICALLY. THE ENGINEERING DIRECTORATE AT NSF IS RESPONSIBLE FOR THE DOCUMENT OBJECTIVES OF SEISMIC DESIGN AND ENGINEERING RESEARCH, AND PREPAREDNESS PLANNING AND HAZARD AWARENESS. THESE TWO OBJECTIVES INCLUDE FUNDAMENTAL AND APPLIED ENGINEERING RESEARCH, MODERNIZATION OF EXISTING FACILITIES, AND SOCIETAL RESPONSE RESEARCH.

THE EARTHQUAKE ENGINEERING RESEARCH PROGRAM AT NSF BEGAN IN THE EARLY 1960'S WITH A BUDGET OF LESS THAN ONE MILLION DOLLARS. THE PROGRAM GREW STEADILY, AND WITH THE PASSAGE OF THE NATIONAL

EARTHQUAKE HAZARDS REDUCTION PROGRAM ACT (1977), THE PROGRAM CONTINUED TO EXPAND TO ITS CURRENT LEVEL OF $15.1 MILLION.

THE EHM PROGRAM IS DIVIDED INTO FOUR ELEMENTS FOR OPERATIONAL PURPOSES. THESE ARE:

SITING AND GEOTECHNICAL SYSTEMS -

RESEARCH IN THIS AREA ADDRESSES THE FUNDAMENTAL ENGINEERING ISSUES RELATED TO EARTHQUAKE GROUND SHAKING AND DESCRIBES EARTHQUAKE INTERACTIONS ON GEOLOGIC STRUCTURES INCLUDING SURFACE AND SUBSURFACE SOIL AND ROCK SYSTEMS. THE PRIMARY RESEARCH AREAS ARE STRONG GROUND MOTION, STABILITY OF GEOTECHNICAL SYSTEMS, TSUNAMI SYSTEMS ENGINEERING AND LIFELINE SYSTEMS.

STRUCTURAL SYSTEMS -

THIS PROGRAM ELEMENT SUPPORTS RESEARCH AIMED AT DEVELOPING THE CAPABILITIES TO PREDICT THE BEHAVIOR OF STRUCTURES DURING EARTHQUAKES, ESTABLISH PRACTICAL GUIDELINES AND METHODS FOR ENGINEERING DESIGN AGAINST EARTHQUAKE LOADING, AND PROVIDE ECONOMICALLY FEASIBLE METHODS TO STRENGTHEN EXISITING HAZARDOUS STRUCTURES. SOME SPECIFIC RESEARCH AREAS ARE DYNAMIC NONLINEAR SYSTEMS, NEW AND RELIABLE DESIGN METHODOLOGIES, COMPUTER SIMULATION, KNOWLEDGE-BASED COMPUTER SYSTEMS, DAMAGE ASSESSMENT METHODOLOGIES AND LIFELINE SYSTEMS.

ARCHITECTURAL AND MECHANICAL SYSTEMS -

RESEARCH IN THIS PROGRAM IS FOCUSED ON ARCHITECTURAL AND MECHANICAL COMPONENTS AND SYSTEMS WHOSE FAILURE DURING AN EARTHQUAKE COULD RESULT IN LOSS OF LIFE, DAMAGE, ECONOMIC LOSSES AND SOCIAL DISRUPTION. EXAMPLES ARE ARCHITECTURAL AND MECHANICAL COMPONENTS IN BUILDINGS SUCH AS GLASS AND EXTERIOR CLADDING, ELEVATORS, BUILDING MECHANICAL SYSTEMS, POWER GENERATION AND TRANSMISSION FACILITIES, BUILDING CONTENTS, COMMUNICATION SYSTEMS AND MASONRY STRUCTURES IN WHICH ARCHITECTURAL AND STRUCTURAL SYSTEMS MAY BE INTEGRAL. MOTION MITIGATION SYSTEMS SUCH AS DAMPERS, ACTIVE CONTROL SYSTEMS AND BASE ISOLATION DEVICES ARE ALSO CONSIDERED.

EARTHQUAKE SYSTEMS INTEGRATION -

THIS RESEARCH SUPPORTS RESEARCH AND RELATED ACTIVITIES FOR THE INTEGRATION OF KNOWLEDGE-PRODUCING AND KNOWLEDGE-USING SYSTEMS. KEY AREAS OF RESEARCH INCLUDE EARTHQUAKE MITIGATION PLANNING; EARTHQUAKE PREPAREDNESS PLANNING; IMPACTS, RECOVERY AND RECONSTRUCTION; AND TECHNOLOGY DELIVERY.

ADDITIONALLY, THE EHM PROGRAM INTERACTS WITH OTHER PROGRAMS AT NSF. THE ENGINEERING PROGRAM IS COORDINATED WITH THE EARTH SCIENCES DIVISION IN THE GEOSCIENCES DIRECTORATE. OTHER

ENGINEERING PROGRAMS WHICH ARE COORDINATED WITH THE EHM PROGRAM ARE THE GEOTECHNICAL ENGINEERING PROGRAM AND THE COMPUTATIONAL ENGINEERING PROGRAM.

NSF ALSO IS A PARTICIPANT IN THE INTERAGENCY COMMITTEE ON SEISMIC SAFETY IN CONSTRUCTION (ICSSC). THIS PROVIDES THE OPPORTUNITY TO COORDINATE NSF'S RESEARCH WITH THE NEEDS OF OTHER FEDERAL AGENCIES AND THE CONTRIBUTING AGENCIES.

SINCE THE MID-1970'S, INTERNATIONAL COMPETITIVENESS IN EARTHQUAKE ENGINEERING HAS BECOME A GLOBAL ISSUE. THIS IS A RESULT OF THE INTERNATIONAL INTEREST IN CONSTRUCTION AND INFRASTRUCTURE PROJECTS, THE DISASTROUS IMPACT AN EARTHQUAKE CAN HAVE ON THE ECONOMY OF A COUNTRY, AND THE GENERAL DESIRE FOR TECHNICAL MARKET DOMINANCE BY CERTAIN COUNTRIES. SINCE EARTHQUAKES ARE AN INTERNATIONAL PROBLEM, THERE IS A GREAT DEAL OF WORLD WIDE INTEREST IN EARTHQUAKE HAZARD MITIGATION. AS A RESULT, THE RELATIONSHIP OF NSF EARTHQUAKE ENGINEERING RESEARCH TO THE INTERNATIONAL BUSINESS AND POLITICAL CLIMATE IS IMPORTANT. OUR RESEARCH RESULTS ARE AVAILABLE IN THE LITERATURE AND ARE USED BY FOREIGN AS WELL AS U.S. INDUSTRY IN COMPETING FOR ENGINEERING AND CONSTRUCTION PROJECTS THROUGHOUT THE WORLD. THUS IT IS NECESSARY THAT U.S. RESEARCH BE AT THE CUTTING-EDGE AND THAT U.S. ENGINEERS (INDUSTRY) TAKE ADVANTAGE OF TRANSLATING RESEARCH RESULTS FOR APPLICATION IN A COMPETITIVE ENVIRONMENT. HENCE, IT IS IMPORTANT THAT U.S. ENGINEERS BE TRAINED BY U.S. UNIVERSITIES AND INSTITUTIONS TO BE ABLE TO ACCOMPLISH THIS.

SINCE THE EHM PROGRAM BEGAN, THE ACCOMPLISHMENTS OF THE PROGRAM HAVE BEEN MANY. RESEARCH PROJECTS HAVE LEAD TO INTERNATIONALLY-RECOGNIZED NEW CONCEPTS AND METHODOLOGIES WHICH HAVE THEN BEEN USED IN FURTHUR DEVELOPMENT OF EARTHQUAKE HAZARD MITIGATION TECHNOLOGY. A NUMBER OF EXAMPLES ARE:

- A FRAMEWORK OF UNDERSTANDING TO EXPLAIN LIQUEFACTION PHENOMENA IN SOILS SUBJECTED TO STRONG GROUND SHAKING AND AN EXTENSION OF THIS KNOWLEDGE TO PREDICT LIQUEFACTION POTENTIAL AT VARIOUS SITES.
- DEPLOYMENT OF RESEARCH STRONG MOTION INSTRUMENTS AND ARRAYS TO CAPTURE GROUND MOTION DATA BOTH IN THE U.S. AND ABROAD.
- DEVELOPMENT OF SPECIAL WORKSHOPS AND CONFERENCES TO FOCUS ON THE NEED FOR GROUND MOTION MICROZONATION TECHNIQUES AND FOR COMPLETELY NEW METHODS TO CHARACTERIZE STRONG GROUND MOTION FOR ENGINEERING DESIGN.
- DEVELOPMENT OF METHODOLOGIES TO INVESTIGATE THE EFFECTS OF EARTHQUAKES ON PIPELINES AND BURIED LIFELINE FACILITIES.
- STUDIES TO UNDERSTAND THE MECHANISMS RESPONSIBLE FOR GROUND AMPLIFICATION OF STRONG EARTHQUAKE GROUND MOTIONS IN SOILS AT TECTONIC AND ENGINEERING SCALES.

- INITIATION OF A SPECIAL EFFORT TO RAPIDLY INCORPORATE THE LATEST DEVELOPMENTS IN MICROELECTRONICS OR OTHER FIELDS INTO ADVANCED INSTRUMENTATION.

- SUPPORT AND DEVELOPEMNT OF 20 X 20 FT. 2-AXIS SHAKING TABLE AT UNIVERSITY OF CALIFORNIA, BERKELEY.

- PARTICIPATION IN DEVELOPMENT OF 12 X 12 FT. 5-AXIS SHAKING TABLE AT SUNY/BUFFALO.

- DEVELOPMENT OF OTHER SPECIALIZED EXPERIMENTAL RESEARCH FACILITIES SUCH AS 2-AXIS REACTION WALL AT THE UNIVERSITY OF TEXAS.

- DEVELOPMENT OF ATC-3 MODEL STANDARD FOR SEISMIC DESIGN OF BUILDINGS AND OTHER STRUCTURES.

- PARTICIPATION IN SIGNIFICANT INTERNATIONAL COOPERATIVE EFFORTS SUCH AS THE U.S.-YUGOSLAVIA PROGRAM AND THE U.S.-JAPAN PROGRAMS ON LARGE-SCALE TESTING.

- SUPPORT OF BASIC RESEARCH FOR IMPLEMENTATION OF THE BASE ISOLATION CONCEPT IN THE U.S. AT THE FOOTHILL COMMUNITIES LAW AND JUSTICE CENTER, SAN BERNARDINO COUNTY, CALIFORNIA.

- DEVELOPMENT WITH INDUSTRY OF NEW METHODOLOGY FOR RETROFIT TO INCREASE SEISMIC RESISTANCE OF UNREINFORCED MASONRY STRUCTURES.

- SUPPORT OF MAJOR COORDINATED RESEARCH PROGRAM AIMED AT PROVIDING RATIONAL KNOWLEDGE BASE FOR REINFORCED MASONRY STRUCTURES.

- RESEARCH ON AND IMPLEMENTATION OF KNOWLEDGE ON DESIGN METHODS TO IMPROVE SEISMIC RESISTANCE OF ELECTRICAL TRANSMISSION LINES, GENERATING FACILITIES AND ELECTRICAL EQUIPMENT.

- MODELS HAVE BEEN DEVELOPED PREDICTING THE DEGREE OF DIFFICULTY THAT CAN BE EXPECTED IN IMPLEMENTING CERTAIN TYPES OF MITIGATION STRATEGIES.

- KEY TECHNICAL AND MANAGERIAL PROBLEMS ASSOCIATED WITH THE IMPACTS AND RESPONSES TO EARTHQUAKES HAVE BEEN IDENTIFIED AS A RESULT OF POST-DISASTER INVESTIGATIONS CONDUCTED IN THE U.S. AND ABROAD.

- MAJOR PRINCIPLES OF EARTHQUAKE MITIGATION AND PREPAREDNESS PLANNING HAVE BEEN DETERMINED AND SERVE AS THE BASIS FOR ACTION BY SUCH ORGANIZATIONS AS FEMA, THE SOUTHERN CALIFORNIA EARTHQUAKE PREPAREDNESS PROJECT AND THE CENTRAL UNITED STATES EARTHQUAKE CONSORTIUM.

- AN ASSESSMENT OF THE FIRE POTENTIAL FOLLOWING EARTHQUAKES IN THE U.S. HAS BEEN COMPLETED AND COMPARED WITH THE LEVEL OF PREPAREDNESS.

- COMPREHENSIVE INFORMATION DISSEMINATION PROGRAMS HAVE BEEN SUPPORTED INCLUDING THE NATIONAL INFORMATION SERVICE FOR EARTHQUAKE ENGINEERING AND THE NATURAL HAZARDS INFORMATION CENTER.

- A PROGRAM OF WORKSHOPS AND CONFERENCES HAVE BEEN DEVELOPED FOR ARCHITECTS AND OTHER DESIGN PROFESSIONALS.

- SELECTED SEISMIC SAFETY INFORMATION PROGRAMS IN THE U.S. HAVE BEEN STUDIED TO DETERMINE THEIR EFFECTIVENESS IN ACHIEVING THEIR GOALS.

THE PAST FISCAL YEAR WAS A BUSY ONE FOR THE EHM PROGRAM. ACTIVITIES WERE DRIVEN BY THE OCCURRENCE OF TWO LARGE EARTHQUAKES AND THE IMPORTANCE IN PROVIDING A SYSTEMS ENGINEERING APPROACH TO EARTHQUAKE ENGINEERING.

RESEARCH ON MARCH 3, 1985, CHILEAN EARTHQUAKE

THE CHILEAN EARTHQUAKE WHICH OCCURRED OFFSHORE OF CENTRAL CHILE CAUSED STRONG SHAKING IN THE COASTAL CITIES OF SAN ANTONIO, VALPARAISO, AND VINA DEL MAR, AND INLAND TO THE CAPITAL, SANTIAGO. AN ESTIMATED $2 BILLION IN DAMAGE OCCURRED WITH 176 REPORTED FATALITIES, ABOUT 2,500 PERSONS INJURED, AND THOUSANDS LEFT HOMELESS.

NSF SUPPORTED A JOINT EARTHQUAKE ENGINEERING RESEARCH INSTITUTE (EERI) AND NATIONAL ACADEMY OF ENGINEERING (NAE) TEAM WHICH WAS IMMEDIATELY DISPATCHED TO CHILE TO CAPTURE PERISHABLE DATA. BASED ON THIS RECONNAISSANCE, EERI ORGANIZED AND HELD A BRIEFING OF THE CHILEAN FIELD INVESTIGATIONS AT THE U.S. GEOLOGICAL SURVEY IN RESTON, VIRGINIA, ON JULY 18-19, 1985. OVER 200 PERSONS ATTENDED THE BRIEFING AND HEARD REPORTS ON THE SEISMOLOGICAL ASPECTS OF THE EARTHQUAKE; THE PERFORMANCE OF BUILDINGS, INDUSTRIAL FACILITIES, BRIDGES AND LIFELINES; AND REPORTS ON ARCHITECTURAL, SOCIOECONOMIC, AND HEALTH CARE ASPECTS. TOPICS FOR FUTURE RESEARCH IN THIS EARTHQUAKE WERE IDENTIFIED AT THE CONCLUSION OF THE BRIEFING.

AS A RESULT OF THE EERI BRIEFING, RESEARCH PROPOSALS WERE RECEIVED AND EIGHT GRANTS WERE MADE BY NSF TO PERFORM RESEARCH RELATED TO THIS EARTHQUAKE WHICH HAS IMPLICATIONS FOR AND APPLICATION TO EARTHQUAKE ENGINEERING IN THE UNITED STATES.

RESEARCH ON THE 19 SEPTEMBER 1985 MEXICO EARTHQUAKE

A MAJOR EARTHQUAKE STRUCK MEXICO ON THE MORNING OF SEPTEMBER 19, 1985. NUMEROUS BUILDINGS DESIGNED UNDER BUILDING CODE STANDARDS COMPARABLE TO THOSE USED IN PARTS OF THE UNITED

STATES WERE SEVERELY SHAKEN - BOTH IN THE EPICENTRAL REGION ALONG THE PACIFIC COAST AND IN MEXICO CITY. IN BOTH AREAS STRONG MOTION INSTRUMENTS PROVIDED SOME COVERAGE OF THE GROUND MOTIONS AND OF THE EFFECTS OF LOCAL SOIL AND GEOLOGICAL CONDITIONS UPON THESE MOTIONS. THERE WERE MANY INSTANCES OF COLLAPSE OR SEVERE DAMAGE OF STRUCTURES AS WELL AS MANY EXAMPLES OF EXCELLENT PERFORMANCE. LIFELINE SYSTEMS WERE PUT TO THE TEST. EMERGENCY RESPONSE PROCEDURES WERE SEVERELY STRAINED. IN SHORT, THIS EARTHQUAKE SIGNIFICANTLY TESTED EARTHQUAKE HAZARD MITIGATION PRACTICES.

AS PART OF NSF'S EXISTING PROGRAMS, QUICK RESPONSE TEAMS ASSEMBLED BY THE EARTHQUAKE ENGINEERING RESEARCH INSTITUTE AND THE NATIONAL ACADEMY OF ENGINEERING WERE DISPATCHED TO THE EARTHQUAKE AREA TO DOCUMENT HIGHLY PERISHABLE ENGINEERING INFORMATION. A PUBLIC BRIEFING MEETING ON THE RECONNAISSANCE WORK WAS HELD TO DISCUSS POSSIBLE FOLLOW UP ACTIONS REQUIRED TO MAXIMIZE LEARNING FROM THE EARTHQUAKE. THIS MEETING WAS HELD IN SAN FRANCISCO AND WAS ATTENDED BY OVER 600 PERSONS.

A JOINT PANEL WAS FORMED BY THE NATIONAL ACADEMY OF ENGINEERING AND THE CONSEJO NACIONAL DE CIENCIA Y TECHNOLOGIA (MEXICAN NSF) TO PREPARE A REPORT DETAILING POTENTIAL RESEARCH TOPICS OF IMPORTANCE. UNSOLICITED PROPOSALS WERE ENCOURAGED BY NSF'S EARTHQUAKE ENGINEERING PROGRAM BASED ON THIS REPORT. NSF MADE 28 AWARDS TO U.S. INVESTIGATORS UNDER THIS PROGRAM. THESE PROJECTS

ARE IDENTIFYING LESSONS THAT CAN BE LEARNED FROM THE MEXICO EARTHQUAKE EXPERIENCE THAT HAVE RELEVANCE TO MITIGATION AND PREPAREDNESS IN THE U.S. THE INVESTIGATORS ARE ALSO WORKING COOPERATIVELY WITH MEXICAN COUNTERPARTS.

EARTHQUAKE ENGINEERING RESEARCH CENTER

IN A PROBLEM FOCUSED AREA SUCH AS EARTHQUAKE ENGINEERING IT IS VERY IMPORTANT TO CONDUCT RESEARCH IN AN INTEGRATED MANNER USING THE SYSTEMS APPROACH. TO ACCOMPLISH THIS, NSF PROPOSED ESTABLISHING AN EARTHQUAKE ENGINEERING RESEARCH CENTER TO SUPPLEMENT THE TRADITIONAL INDIVIDUAL INVESTIGATOR APPROACH AND WHERE EARTHQUAKE HAZARD MITIGATION PROBLEMS COULD BE EXAMINED IN A SYSTEMATIC INTERDISCIPLINARY MANNER.

AN EARTHQUAKE ENGINEERING RESEARCH CENTER WAS COMPETITIVELY AWARDED TO THE STATE UNIVERSITY OF NEW YORK (SUNY), BUFFALO IN AUGUST 1986. THE CENTER IS A COOPERATIVE $10 MILLION PER YEAR RESEARCH OPERATION WITH NSF PROVIDING $5 MILLION PER YEAR AND THE MATCHING BALANCE PROVIDED FROM STATE AND NON-FEDERAL FUNDS.

ALTHOUGH THE AWARD IS TO BUFFALO, WHICH WILL SERVE AS A FOCAL POINT FOR THE CENTER'S ACTIVITIES, THE NEW FACILITY WILL INVOLVE THE COORDINATED EFFORTS OF THE CITY COLLEGE OF NEW YORK, COLUMBIA UNIVERSITY, CORNELL UNIVERSITY, LAMONT-DOHERTY GEOLOGICAL

OBSERVATORY, LEHIGH UNIVERSITY, PRINCETON UNIVERSITY AND RENSSELAER POLYTECHNIC INSTITUTE. THE CENTER WILL BE DIRECTED BY DR. ROBERT L. KETTER, LEADING PROFESSOR OF ENGINEERING AND APPLIED SCIENCES.

THE CENTER WILL CONDUCT RESEARCH TO IMPROVE BASIC KNOWLEDGE ABOUT EARTHQUAKES, ENGINEERING PRACTICE AND THE IMPLEMENTATION OF SEISMIC HAZARD MITIGATION PROCEDURES TO MINIMIZE THE LOSS OF LIVES AND PROPERTY. THE CENTER ALSO WILL BE A NATIONAL FOCAL POINT FOR EARTHQUAKE ENGINEERING RESEARCH AND ENHANCE THE INTERNATIONAL COMPETITIVENESS OF THE U.S. THROUGH CLOSE INTERACTION WITH THE PRACTICING ENGINEERING COMMUNITY.

MAJOR AREAS OF STUDY INITIALLY WILL BE DIRECTED TOWARD BUILDINGS AND OTHER STRUCTURES BUILT BEFORE THE NEED TO MITIGATE THE EFFECTS OF EARTHQUAKES WAS REALIZED. ANOTHER INITIAL EFFORT WILL BE DIRECTED TOWARD THE EARTHQUAKE RISK PRESENTED BY AREAS WHICH COULD HAVE A HIGH INTENSITY EARTHQUAKE BUT WITH LOW FREQUENCY SUCH AS EXISTS IN THE EASTERN U.S. EMPHASIS WILL BE GIVEN TO A SYSTEMS APPROACH IN WHICH EARTHQUAKE REQUIREMENTS ARE INTEGRATED WITH CONSIDERATION OF OTHER HAZARDS SUCH AS HIGH WINDS AND GROUND FAILURES.

SCIENTIFIC KNOWLEDGE BASE FOR MASONRY RESEARCH PROGRAM

A COOPERATIVE RESEARCH PROJECT WITH JAPAN ON THE SEISMIC RESISTANCE OF MASONRY BUILDINGS WAS BEGUN IN FY 1986. THIS ACTIVITY IS COORDINATED WITH A SIMILAR PROJECT BY THE BUILDING RESEARCH INSTITUTE OF JAPAN AS PART OF THE CONTINUING ACTIVITY OF THE TASK COMMITTEE ON LARGE-SCALE EXPERIMENTS OF THE PANEL ON WIND AND SEISMIC EFFECTS UNDER THE U.S.-JAPAN COOPERATIVE PROGRAM IN NATURAL RESOURCES AGREEMENT. THE U.S. RESEARCH PROGRAM CONSISTS OF A SERIES OF COORDINATED RESEARCH TASKS BEGINNING WITH THOSE WHICH ADDRESS BASIC MATERIAL BEHAVIOR, PROGRESSING TO TASKS ADDRESSING BEHAVIOR OF MASONRY STRUCTURAL COMPONENTS SUCH AS WALLS, TO EXPERIMENTS ON A FULL-SIZE RESEARCH BUILDING.

DEVELOPMENT OF ANALYTICAL METHODS FOR STRESS AND STRAIN ANALYSIS AND SYSTEM BEHAVIOR WILL PROCEED IN PARALLEL WITH EXPERIMENTAL TASKS. THE FINAL TASK WILL BE THE PREPARATION OF RECOMMENDATIONS FOR DESIGN PROCEDURES AND BUILDING CODE PROVISIONS.

COMPLETION OF THIS 5 TO 6 YEAR PROGRAM SHOULD RESULT IN THE SAFE CONSTRUCTION OF MASONRY STRUCTURES IN ALL EARTHQUAKE ZONES IN A ECONOMIC AND COMPETITIVE MANNER.

STRUCTURAL SYSTEMS LABORATORY

THE CHARLES LEE POWELL STRUCTURAL SYSTEMS LABORATORY AT THE UNIVERSITY OF CALIFORNIA AT SAN DIEGO WAS COMPLETED DURING THE PAST YEAR. IT IS A RESEARCH FACILITY FOR THE EXPERIMENTAL TESTING OF FULL AND LARGE SCALE STRUCTURAL COMPONENTS AND SYSTEMS SUCH AS BUILDINGS, BRIDGES, OFFSHORE STRUCTURES, ETC. NSF PROVIDED COOPERATIVE FUNDING TO ASSURE THAT THE DESIGN WOULD ACCOMMODATE THE NEEDS OF THE MASONRY RESEARCH PROGRAM WHICH IS COORDINATED WITH A PARALLEL JAPANESE EFFORT. NSF IS ALSO PROVIDING SUPPORT TO HELP EQUIP THE LABORATORY WITH HYDRAULIC LOADING AND DATA ACQUISITION EQUIPMENT NEEDED TO CARRY OUT THE PROGRAM.

A FULL-SCALE FIVE STORY MASONRY RESEARCH BUILDING WILL BE TESTED IN THE LABORATORY IN CONJUNCTION WITH THE RESEARCH PROGRAM. WITH THE SAN DIEGO SUPERCOMPUTER CENTER LOCATED ON THE CAMPUS, THIS LABORATORY WILL HAVE THE UNIQUE CAPABILITY TO DEVELOP STATE-OF-THE-ART INTERACTIVE COMPUTER CONTROLLED STRUCTURAL TESTING PROCEDURES.

UPGRADE OF UNIVERSITY OF CALIFORNIA, BERKELEY EARTHQUAKE SIMULATION FACILITY

AS PART OF NSF'S CONTINUING ACTIVITY TO UPGRADE EXISTING EARTHQUAKE ENGINEERING EXPERIMENTAL FACILITIES, SIGNIFICANT RESOURCES HAVE BEEN AWARDED TO THE UNIVERSITY OF CALIFORNIA BERKELEY TO PROVIDE FOR ADVANCED HYDRAULIC-ACTUATOR EQUIPMENT AND CONTROLS. THIS WILL ALLOW THE EARTHQUAKE SIMULATOR TO BE ABLE TO BE USED FOR MORE COMPLEX RESEARCH PROBLEMS.

IMPLEMENTATION

THE NSF EARTHQUAKE HAZARD MITIGATION PROGRAM HAS MADE MAJOR CONTRIBUTIONS TOWARD THE GOALS OF REDUCTION OF LOSS OF RESOURCES AND LIVES DUE TO THE OCCURRENCE OF EARTHQUAKES. FUTURE PLANS CONTINUE TO BE TARGETED TOWARD CHANGING TECHNOLOGY AND CHANGING USER NEEDS TO ASSURE THAT THE U.S. REMAINS IN A LEADING COMPETITIVE POSITION IN THIS FIELD.

NSF WILL CONTINUE TO DISSEMINATE RESEARCH RESULTS TO USERS AND TO COOPERATE WITH OTHER RELEVANT AGENCIES IN SUCH ACTIVITIES. THE DISSEMINATION EFFORTS ARE AIMED AT DIVERSE AUDIENCES, INCLUDING ENGINEERS, ARCHITECTS, BUILDING OFFICIALS, GOVERNMENT OFFICIALS, AND RESEARCHERS. NUMEROUS CHANNELS OF COMMUNICATION ARE USED TO INFORM USERS OF RELEVANT RESEARCH RESULTS. THE NATURAL HAZARDS INFORMATION CENTER AT THE UNIVERSITY OF COLORADO AND THE NATIONAL

INFORMATION SERVICE FOR EARTHQUAKE ENGINEERING AT THE UNIVERSITY OF CALIFORNIA-BERKELEY AND THE CALIFORNIA INSTITUTE OF TECHNOLOGY ARE CENTRAL TO THIS DISSEMINATION PROGRAM.

IN RECENT YEARS, SIGNIFICANT EXPANSION HAS OCCURRED IN THE KNOWLEDGE BASE IN THE EARTHQUAKE HAZARD MITIGATION FIELD. AS A RESULT, NEW INFORMATION SYSTEMS ARE NEEDED TO FACILITATE THE DISSEMINATION AND UTILIZATION OF RESEARCH RESULTS IN THE AREA. NSF IS SUPPORTING DEVELOPMENT OF A PROTOTYPE DATA STORAGE AND RETRIEVAL SYSTEM FOR EARTHQUAKE ENGINEERING AND RELATED EARTHQUAKE HAZARD MITIGATION DISCIPLINES. IN DEVELOPING THIS SYSTEM, THE RESEARCH IS TAKING ADVANTAGE OF RECENT ADVANCES IN THE FIELDS OF MEMORY TECHNOLOGY, DATA COMPRESSION, COMPUTER GRAPHICS AND DISPLAY TECHNOLOGY. WHEN COMPLETED, THE SYSTEM WILL ALLOW FOR THE WIDE DISSEMINATION OF LARGE VOLUMES OF TEXTUAL AND IMAGE DATA AT AN AFFORDABLE COST TO USERS.

EARTHQUAKE ENGINEERING IS A GLOBAL ENDEAVOR. IT IS IMPORTANT THAT U.S. DESIGNS AND PRODUCTS BE COMPETITIVE ON THE WORLD MARKET. THEREFORE, RESEARCH MUST BE CONDUCTED THAT WILL MAKE U.S. EARTHQUAKE TECHNOLOGY THE LEADING TECHNOLOGY WHICH IS ALSO COST EFFECTIVE ON INTERNATIONAL PROJECTS. AS A PART OF THIS ISSUE, PARTICIPATION IN INTERNATIONAL PROGRAMS NEEDS TO BE CONTINUED AND ACCELERATED SUCH THAT THE U.S. CAN REMAIN A COMPETITIVE FORCE IN THE INTERNATIONAL MARKET. THIS INCLUDES

TAKING ADVANTAGE OF ANY DATA THAT ARE GENERATED BECAUSE OF THE OCCURRENCE OF FOREIGN EARTHQUAKES FOR USE IN APPLICATION TO U.S. GENERATED MITIGATION EFFORTS. COOPERATIVE RESEARCH EFFORTS IS AN EFFECTIVE WAY OF ACHIEVING THIS.

SUMMARY

SINCE THERE IS AN ACTIVE AND COMPETITIVE GLOBAL INTEREST IN EARTHQUAKE ENGINEERING, IT IS NECESSARY THAT THE U.S. LEAD THE FIELD IN THIS TECHNOLOGY. ONE TECHNIQUE FOR DOING THIS IS THE RAPID ASSIMINATION OF NEW TECHNOLOGIES TO THE PROCESS OF EARTHQUAKE ENGINEERING RESEARCH AND PRACTICE. EXAMPLES WOULD INCLUDE MICRO-ELECTRONICS AND BETTER UTILIZATION OF COMPUTERS.

THE EHM PROGRAM HAS, IN THE PAST, SUPPORTED RESEARCH ON EXAMINING APPROACHES TO MULTI-HAZARD MITIGATION AND PREPAREDNESS PLANNING AND WAYS IN WHICH SEISMIC SAFETY PLANNING CAN BE INTEGRATED INTO GENERAL PLANNING EFFORTS AND THE CONSEQUENCES OF SUCH ACTIONS. THIS, AND OTHER MITIGATION AND PREPAREDNESS PLANNING RESEARCH, WILL BE CONTINUED WITH A FAST TRACK TOWARD IMPLEMENTATION. THIS WILL BE MOST USEFUL TO SEISMIC SAFETY ENGINEERS, ARCHITECTS, PLANNERS AND DESIGN PROFESSIONALS.

NEW AND INNOVATIVE APPROACHES TO DESIGN AND ANALYSIS NEED TO BE EXAMINED. THE APPLICATION OF ARTIFICIAL INTELLIGENCE AND EXPERT

SYSTEMS METHODS TO MITIGATION AND DESIGN IS ONE ADVANCED TECHNOLOGY THAT CAN INCORPORATE EXISTING DATA AND KNOWLEDGE INTO THE PROCESS. THE EHM PROGRAM IS AGGRESSIVELY SUPPORTING RESEARCH ADVANCING THESE NEW TECHNOLOGIES.

I THANK YOU FOR THE OPPORTUNITY TO GIVE A BRIEF SUMMARY OF THE NSF ENGINEERING EARTHQUAKE HAZARD MITIGATION PROGRAM ACTIVITIES.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

NAM P. SUH
Assistant Director
for Engineering

Dr. Nam P. Suh was appointed Assistant Director for Engineering by President Reagan. His appointment was effective October 16, 1984.

Prior to his appointment at the National Science Foundation, Dr. Suh served as Professor of Mechanical Engineering at the Massachusetts Institute of Technology and Director of the Laboratory for Manufacturing and Productivity, which is the center for productivity and manufacturing research and education at the Institute. He had also served as the Director of the MIT-Industry Polymer Processing Program since its founding in 1973. Dr. Suh was Head of the Mechanics and Materials Division, Department of Mechanical Engineering at MIT. Dr. Suh served as Director of Surtech Corporation of New Hampshire, Director of Intelitec Corporation, and Chairman of the Board of Axiomatics Corporation and Mixalloy Corporation.

Dr. Suh's primary fields of research have been manufacturing, tribology, materials processing, special materials, and design. Among his accomplishments in these fields are developments of new advanced cutting tools, the mixalloying process, the delamination theory of wear, solution wear theory, the introduction of the axioms for design and manufacturing, a new NDE technique based on the charge decay concept, development of wear resitant materials, a new friction theory, and many new and commercially successful polymer processing techniques such as the USM process, foam lamination process, and electrical-mechanical hybrid mixing. He also introduced the concept of thermo-mechanical effects in the solid phase reaction and a theory for super rate burning of solid propellants. Over 130 publications and 25 patents have resulted from his work in addition to a textbook entitled Elements of the Mechanical Behavior of Solids and a reference book entitled Tribophysics.

Dr. Suh was born in Korea. He graduated from MIT (S.B., 1959; S.M., 1961) and Carnegie-Mellon University (Ph.D., 1964).

Dr. and Mrs. Suh have four children and their permanent residence is in Sudbury, Massachusetts.

February 1987

Mr. BOEHLERT. Thank you, Dr. Suh. Let's proceed with Dr. Hays.

Mr. HAYS. With your permission, I will also summarize my written statement.

Mr. BOEHLERT. Your full statement will appear in its entirety in the record.

Mr. HAYS. You have heard about the earthquake engineering research program at the Foundation. The Foundation also supports basic research into the earthquake process itself and into the crustal motions and plate tectonics that provide the ultimate causes of earthquakes.

These studies are part of the Foundation's regular earth science research program but they also serve as the fundamental earthquake studies element of the National Earthquake Hazard Reduction Program. They form the basic scientific basis for more applied programs in earthquake predictions and ground motion, studies of that type.

I'd like to speak just briefly about a few examples of projects in this program. If you drive north of San Bernardino on Interstate 15 these days, as you climb up over Cajon Pass, if you look to the right of the highway, you see a very large drill rig that sits just a few 100 yards away from the road. That's the site of the Cajon Pass scientific drilling project.

The aim of this project is to drill a 3 mile deep hole right along the San Andreas fault. Now, the purpose of that hole is to be able to measure temperatures, stress, and pore pressures right in the vicinity of the fault. This data will allow an understanding of the mechanisms of the fault and solve some very puzzling aspects of the mechanics of the San Andreas fault.

At the close of that project, the hole will then be instrumented and left as an in-situ observatory to listen in on future movements along the fault. That project is jointly supported by the Foundation and by the Geological Survey. It's operated by a group called DOSECC, which is a consortium of 35 universities.

The second project I'd like to mention is one recently completed by Professor George McMechan at the University of Texas in collaboration with some colleagues from the Geological Survey. Dr. McMechan has developed a technique for imaging the source region of an earthquake. It involves deploying an array of digital seismometers, recording signals from an earthquake and then projecting these backward in time to actually form an image of the fault surface along which the earthquake occurred.

I think this is potentially a very powerful tool for understanding the details of how and why earthquakes occur.

The third project I would mention makes use of the Department of Defense's NAVSTAR Global Positioning System satellites, the GPS system. Using this system with a small portable receiver that can be taken out into the field, it is possible to measure horizontal distances that may be up to tens and hundreds of miles with the precision of about plus or minus 1 centimeter. The importance of this is that ground motions and plate motions are on the order of a few centimeters a year, so that with this technology, it should be possible to actually observe ground motions taking place in near real time. This has important implications in monitoring stress buildups, for example, in earthquake prone regions.

Finally, I'd like to mention the IRIS program. IRIS is the acronym for Incorporated Research Institutions in Seismology. This again is university consortium, this time consisting of about 50 university members. This consortium is in the process of developing a new generation of seismic instrumentation. This will be instrumentation both for the upgrading and improvement of the global seismic network and that's carried out in close collaboration with the Geological Survey and also instrumentation to form these portable arrays that will be needed to apply Dr. McMechan's method to the study of individual earthquakes.

The point that I would like to leave you with is that all of these projects are part of the Foundation's normal earth sciences research program. These are all projects that were selected through the merit review process. They are selected on the basis of their scientific excellence. They are chosen in accord with the Foundation's basic mission of supporting the health of research and teaching in the nation's colleges and universities.

At the same time, these projects also form the role envisioned for the Foundation in the fundamental earthquake studies component of the National Earthquake Hazards Reduction Program and they provide the long term scientific basis that will be needed to understand the effects of earthquakes in the future.

I would be glad to answer any questions.

[The prepared statement of Dr. Hays follows:]

TESTIMONY BEFORE THE HOUSE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
10 MARCH 1987

DR. JAMES F. HAYS
DIRECTOR, DIVISION OF EARTH SCIENCES
NATIONAL SCIENCE FOUNDATION

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE

IN ADDITION TO THE EARTHQUAKE ENGINEERING RESEARCH PROGRAM THAT YOU HAVE JUST HEARD ABOUT, THE NATIONAL SCIENCE FOUNDATION ALSO SUPPORTS AS PART OF ITS REGULAR RESEARCH PROGRAMS IN EARTH SCIENCES BASIC RESEARCH ON THE FUNDAMENTAL CAUSES AND CONDITIONS FOR EARTHQUAKE OCCURRENCE INCLUDING RESEARCH ON EARTHQUAKE MECHANISMS, CRUSTAL MOVEMENTS, AND SEISMOLOGY. THESE SUBJECTS FORM THE FUNDAMENTAL EARTHQUAKE STUDIES COMPONENT OF THE NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM AND PROVIDE THE SCIENTIFIC BASIS FOR MORE APPLIED PROGRAMS OF EARTHQUAKE FORECASTING AND PREDICTION, GROUND MOTION PREDICTION, AND THE LIKE.

I WOULD LIKE TO DESCRIBE BRIEFLY FOR YOU SOME OF THE HIGHLIGHTS OF OUR CURRENT PROGRAM IN THIS FIELD:

* AT CAJON PASS, IN CALIFORNIA, A 16,000 FOOT HOLE IS NOW BEING DRILLED ALONGSIDE THE SAN ANDREAS FAULT. THIS PROJECT, JOINTLY SUPPORTED BY NSF AND USGS, IS DESIGNED TO MEASURE TEMPERATURE, STRESS, AND PORE PRESSURE WITHIN THE DEPTH ZONE WHERE EARTHQUAKES ORIGINATE. THESE DATA WILL BE USED TO ANSWER AN IMPORTANT QUESTION ABOUT EARTHQUAKE MECHANICS. AT THE COMPLETION OF THE PROJECT, INSTRUMENTS WILL BE LEFT IN THE DRILLHOLE TO SERVE AS CLOSE-UP LISTENING POSTS NEAR THE FAULT ZONE.

* THE COCORP PROJECT (CONSORTIUM FOR CONTINENTAL REFLECTION PROFILING), LED BY CORNELL UNIVERSITY, AND THE CALCRUST PROJECT, LED BY THE UNIVERSITY OF SOUTHERN CALIFORNIA, ARE USING THE SEISMIC REFLECTION PROFILING TECHNIQUE, PIONEERED BY THE OIL INDUSTRY, TO LOCATE AND MAP CRUSTAL DEEP FAULTS THAT ARE NOT VISIBLE AT THE EARTH'S SURFACE. COCORP OR CALCRUST LINES HAVE NOW BEEN RUN IN 25 OF THE 50 STATES.

* PROFESSOR GEORGE MCMECHAN OF THE UNIVERSITY OF TEXAS, WORKING WITH COLLEAGUES AT USGS AND USING THE METHODS OF ARRAY SEISMOLOGY HAS DEVELOPED A TECHNIQUE FOR IMAGING THE RUPTURE SURFACE OF EARTHQUAKES. THIS TECHNIQUE IS A MAJOR STEP TOWARD UNDERSTANDING HOW AND WHY A PARTICULAR EARTHQUAKE OCCURRED.

* THE FOUNDATION HAS RECENTLY ANNOUNCED AWARDS TO 8 GROUPS OF UNIVERSITY SCIENTISTS TO USE THE SATELLITE-BASED GLOBAL POSITIONING SYSTEM (GPS) TO MAKE PRECISE MEASUREMENTS OF CRUSTAL DEFORMATIONS IN AREAS WHERE ACTIVE MOVEMENTS ARE NOW TAKING PLACE. THESE MEASUREMENTS ARE EXPECTED TO BE HELPFUL IN LOCATING AREAS WHERE EARTHQUAKES ARE LIKELY TO OCCUR.

* IRIS (INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY), A CONSORTIUM OF 50 UNIVERSITIES REPRESENTING 26 STATES, IS WORKING WITH THE USGS TO UPGRADE THE GLOBAL DIGITAL SEISMOGRAPHIC NETWORK. THE PRIMARY PURPOSE OF THIS NETWORK IS TO MAKE POSSIBLE THE IMAGING OF THE EARTH'S INTERIOR INCLUDING THE CONVECTION CURRENTS THAT ARE BELIEVED TO DRIVE THE MOTIONS OF THE CRUSTAL PLATES. IN ADDITION, HOWEVER, THIS NETWORK WILL MAKE POSSIBLE THE RAPID DETECTION AND LOCATION OF EARTHQUAKES ANYWHERE ON EARTH AND THE PROMPT DETERMINATION OF SOURCE MECHANISMS TO FACILITATE AFTERSHOCK AND TSUNAMI PREDICTIONS.

* IRIS IS ALSO DEVELOPING A LARGE ARRAY OF PORTABLE SEISMOGRAPHS THAT CAN BE RAPIDLY DEPLOYED IN THE FIELD TO STUDY EARTHQUAKE SWARMS, AFTERSHOCK PATTERNS, OR TO DETECT BURIED FAULTS AND OTHER CRUSTAL STRUCTURES. THESE PORTABLE SEISMOGRAPHS WILL BE MADE AVAILABLE TO SCIENTISTS FROM COLLEGES AND UNIVERSITIES THROUGHOUT THE COUNTRY FOR USE IN THEIR RESEARCH.

* ABOUT 50 ADDITIONAL GRANTS ARE MADE EACH YEAR TO INDIVIDUAL RESEARCHERS IN COLLEGES AND UNIVERSITIES FOR RESEARCH IN AREAS INCLUDED WITHIN FUNDAMENTAL EARTHQUAKE STUDIES. THE FOUNDATION HAS RECENTLY ISSUED A PROGRAM ANNOUNCEMENT DESIGNED TO ENCOURAGE SUBMISSION OF RESEARCH PROPOSALS IN THIS FIELD.

I WOULD LIKE TO EMPHASIZE THAT ALL OF THESE PROJECTS ARE PART OF THE FOUNDATION'S REGULAR PROGRAM IN EARTH SCIENCES, CHOSEN BY MERIT REVIEW BECAUSE OF THEIR EXCELLENCE AS BASIC SCIENCE. EARTH SCIENCE IS NOW ONE OF THE MOST EXCITING AND RAPIDLY DEVELOPING AREAS OF SCIENCE. FOR THE LAST FIVE YEARS THE NATIONAL SCIENCE FOUNDATION, THROUGH ITS CONTINENTAL LITHOSPHERE PROGRAM, HAS PLACED SPECIAL EMPHASIS ON EARTH SCIENCES IN ITS BUDGET REQUESTS. AS THE OVERALL BUDGET FOR EARTH SCIENCES HAS GROWN, THE PORTION DEVOTED TO EARTHQUAKE STUDIES HAS GROWN AS WELL.

THE ORIGINAL NEWMARK-STEVER REPORT AND THE CURRENT FIVE-YEAR PLAN RECOGNIZE THIS HEALTHY PROGRAM OF BASIC RESEARCH AS AN IMPORTANT COMPONENT OF THE NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM, CONTRIBUTING TO THE BALANCE AND LONG-TERM HEALTH OF THE PROGRAM. THE NATIONAL SCIENCE FOUNDATION AGREES WITH THIS VIEW.

THANK YOU FOR YOUR ATTENTION.

DR. JAMES F. HAYS

BIOGRAPHICAL SKETCH

Dr. James F. Hays is Director of the Division of Earth Sciences at the National Science Foundation. Prior to joining the Foundation in 1982, he was Professor of Geology and Chairman of the Department of Geological Sciences at Harvard University where he had been a member of the faculty since 1966. He has served on advisory committees for NASA and for the Interior and Agriculture Departments. Dr. Hays is a native of Little Rock, Arkansas, and holds degrees in geology from Columbia University, the California Institute of Technology, and Harvard University. He now resides in Arlington, Virginia.

Mr. BOEHLERT. Thank you very much, Dr. Hays. We will turn now to Dr. Lyons.

Mr. LYONS. Thank you, Mr. Chairman. It's my pleasure to appear before the Subcommittee to talk about the National Bureau of Standards' program in earthquake hazard reduction.

This work is all done in the Center for Building Technology and I'm pleased to have with me Dr. Richard Wright, who was introduced earlier by Mr. Walgren.

Mr. BOEHLERT. As you know and he knows, I'm a fan of CBT.

Mr. LYONS. Yes, sir. The Bureau's role in this area is first of all to provide technical support for the development of model seismic design and construction provisions which are suitable for incorporation into good building practice and into the nation's building regulatory system and secondly, to conduct a program of research in support of that first assignment.

First, let me discuss some of our recent work done in cooperation with FEMA. I want to talk about the Interagency Committee on Seismic Safety and Construction and the Building Seismic Safety Committee.

First, on the ICSSC, we now have guidelines out for Federal buildings. These were put out during the year, the blue covered report, and I would like to submit this, Mr. Chairman, for the record.

[Information to be furnished follows:]

NBSIR 87-3524   ICSSC RP-1

SEISMIC DESIGN GUIDELINES FOR FEDERAL BUILDINGS

February 1987

Prepared by:
Interagency Committee on Seismic
Safety in Construction

Sponsored by:
Federal Emergency Management Agency
Washington, DC 20472

and

National Bureau of Standards
Gaithersburg, MD 20899

NBSIR 87-3524 ICSSC RP-1

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

This report, **Seismic Design Guidelines for Federal Buildings)** (referred to as the **Seismic Guidelines**), was prepared by the Interagency Committee on Seismic Safety in Construction as one part of the National Earthquake Hazards Reduction Program, the President's plan to implement the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124). They are intended for consideration and use, as appropriate, by Federal agencies for the planning, design, and construction of buildings, both within and outside the United States.

The **Seismic Guidelines** are intended primarily for use in designing new buildings. They are not intended for the design of special structures such as dams, piers, drydocks, and nuclear facilities. Structures designed in accord with these **Seismic Guidelines** are expected to provide the minimum level of life safety that is considered reasonable. A moderate earthquake would be expected to produce only minor damage; a large earthquake might produce serious damage but would be unlikely to cause the structure to collapse. Structures which must remain functional after an earthquake may warrant a higher level of resistance, and a few structures may warrant a lower level of resistance.

The **Seismic Guidelines** were prepared as a coordinated adaptation of appropriate portions of existing voluntary standards, model building codes, Federal regulations, and research reports. However, they are most closely related to the 1985 **Uniform Building Code** (UBC), published by the International Conference of Building Officials, Whittier, CA. Because several source documents were used, considerable care was exercised to ensure that the resulting guidelines were consistent throughout the report. Effort was also made to ensure that the **Seismic Guidelines** were flexible enough to allow use without modification or to allow inclusion of special agency requirements.

Comments on this report are welcome and solicited. Since certain sections of these guidelines may have not been thoroughly tested or used, they should be incorporated with engineering judgement. Federal agencies using these criteria are requested to document their experience using them. Such information will be used in the periodic review and update of the Guidelines.

Comments should be forwarded to:

Secretariat
Interagency Committee on Seismic Safety in
Construction
Room B260, Building 226
National Bureau of Standards
Gaithersburg, Maryland 20899

OVERVIEW

This report, **Seismic Design Guidelines for Federal Buildings** (also referred to as **Seismic Guidelines**), contains provisions for the reduction of earthquake hazards in Federal buildings. The **Seismic Guidelines** are intended primarily for use in designing new buildings. They are not intended for the design of special structures such as dams, piers, drydocks, and nuclear facilities. The report also contains a commentary on the provisions.

The Guidelines were prepared by a subcommittee of the Interagency Committee for Seismic Safety in Construction (ICSSC) after a review of existing voluntary standards, model building codes, Federal regulations, and research reports. The seismic regulations of the Veterans Administration, Army, Navy, Air Force, General Services Administration, and Department of Housing and Urban Development were all considered in the development of these guidelines.

It is worth emphasizing that this report was originally prepared in response to the requirement in the Implementation Plan of the Earthquake Hazards Reduction Act to develop a uniform set of earthquake design guidelines suitable for uniform use by all agencies. The ICSSC subcommittee charged with this responsibility developed several criteria for preparing these guidelines, (1)they should be as close to current practice in both the public and private sectors as possible and (2)since several Federal agency have extensive seismic programs underway, they should be flexible enough to allow incorporation of special agency requirements. The subcommittee determined that the Uniform Building Code (UBC) met criteria (1) most closely. However, there are three model codes referenced for use in the United States. Thus a determination was made that the guidelines should reference national standards rather than the UBC standards used in the UBC. It also became apparent that there are seismic requirements spread throughout the UBC and not just in the seismic design chapter. Thus it became necessary to reorganize the material somewhat in order to have all of the material required in one document. The report is a self-contained set of seismic guidelines that references national standards, closely resembles the UBC in requirements, and allows inclusion of special agency requirements.

The following documents received special attention and deserve special reference:

NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, Earthquake Hazards Reduction Series 17 and 18, Federal Emergency Management Agency, Washington, DC, 1986.[1]

Recommended Design Loads for Buildings and other Structures, ANSI A 58.1, American Natdional Standards Institute, New York, New York, 1982

Recommended Lateral Force Requirements and Commentary, Structural Engineers Association of California, San Francisco, California, 1978.[2]

Uniform Building Code, International Conference of Building Officials, Whittier, CA, 1985.

Since portions of each document were used in this report, considerable care was exercised to ensure that the resulting guidelines were consistent throughout. Because the seismic provisions of the UBC are the most widely used and because they served as the starting point for these guidelines, particular care is taken to relate these provisions to those of the UBC. Although there are differences with the UBC, owing to different contexts, policies, and styles, the basic technical approach to the analysis of seismic loads and the design of buildings to resist such loads is the same. The Commentary of this report contains a discussion of the differences between these Guidelines and the UBC. Where other sources are used, they are identified.

---

[1] The original draft of this report used the Applied Technology Report, **Tentative Provisions for the Development of Seismic Regulations for Buildings,** NBS SP 510, published by the National Bureau of Standards, 1978 as the resource document. That has undergone considerable review and evaluation since publication and served as the basis of the NEHRP document. The NEHRP document is referenced here since it is a more recent publication and will be updated on approximately a three year cycle.

[2] The Uniform Building Code is based on this report which is also referred to as the SEAOC Requirements in this document. The report, published in 1975 was extremely valuable in interpreting some portions of the intent of the UBC. The SEAOC Requirements have recently undergone a major revision which has been proposed as a code change to the UBC. Since the revision is so different from the current UBC and since the proposal has not yet been incorporated in the UBC, it has not been used in these guidelines.

As with the voluntary standards and codes upon which these guidelines are based, the requirements

> "are intended to provide criteria to fulfill life safety concepts. It is emphasized that the recommended design levels are not directly comparable to recorded or estimated peak ground accelerations from earthquakes. They are however, related to the effective peak accelerations to be expected in seismic events. More specifically with regard to earthquakes, structures designed in conformance with the provisions and principles set forth therein should, in general, be able to:
>
> 1. Resist minor earthquakes without damage;
> 2. Resist moderate earthquakes without structural damage, but with some nonstructural damage;
> 3. Resist major earthquakes, of the intensity of severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage.
>
> In most structures it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. This, however, depends upon a number of factors, including the type of construction selected for the structure."[3]

---

[3] **Recommended Lateral Force Requirements and Commentary**, Structural Engineers Association of California, 1978.

One of the objectives of the commentary is to explain the differences between the provisions of these guidelines and those of their sources. Because the seismic provisions of the UBC are the most widely used and because they served as the starting point for these guidelines, particular care is taken to relate these provisions to those of the UBC. Although there are many differences with the UBC, owing to different contexts, policies, and styles, the basic technical approach to the analysis of seismic loads and the design of buildings to resist such loads is the same.

The commentary also addresses specific issues to assist the user of the guidelines, but it is not a complete commentary on seismic-resistant design. Both the SEAOC and NEHRP provisions are accompanied by extensive commentaries that are recommended reading for users of these guidelines. In addition, the Army, Navy, and Air Force manual **Seismic Design for Buildings** referred to as the Tri-Services Manual) contains guidelines for procedures and details that facilitate implementation of provisions for seismic resistance of buildings.

ACKNOWLEDGEMENTS

This report was originally developed by the members of the Interagency Committee on Seismic Safety in Construction (ICSSC) Subcommittee 2 - Building Standards and published in 1981. In a reorganization of the ICSSC this became Subcommittee 1 - Standards for New and Existing Buildings with a new membership. Subsequently Subcommittee 1 reviewed the original report and, with some modifications reported it to the ICSSC for ballot. The membership of the two subcommittees (denoted in parentheses) consisted of (affiliation at time of participation is shown):

Vartan M. Bedjanian (2)	Naval Facilities Engineering Command, Western Division
Earl R. Bell (1)	Department of Agriculture
Lincoln Chang (2)	Department of Housing and Urban Development
Donald M. Evick (1)	Postal Service
Edward Ference (2)	Naval Facilities Engineering Command
Peter E. Gurvin (1,2)	Department of State
James R. Harris (2)	National Bureau of Standards
James R. Hill (1)	Department of Energy
Boyd H. Lefevre (1)	Department of Transportation
Edgar V. Leyendecker (1,2)*	National Bureau of Standards
Allen Lim (2)	Department of Air Force
George Lippert (1)	Department of Agriculture
Raymond W. Little (1)	Department of Health & Human Services
George M. Matsumura (1,2)	Army Corps of Engineers
Richard D. McConnell (1,2)	Veterans Administration
John Mehnert (1)	Department of Housing and Urban Development
Janina Z. Mirski (1)	Veterans Administration
Howard D. Nickerson (2)	Naval Facilities Engineering Command
William D. Rust, Jr. (1,2)	General Services Administration
John B. Scalzi (1,2)	National Science Foundation
Constantine Spyropoulos (1,2)	Department of Housing and Urban Development
Joseph Tyrrell (1)	Naval Facilities Engineering Command
Marco F. Venturino (1,2)	Naval Facilities Engineering Command, Western Division
Spencer Wu (1)	National Bureau of Standards
Michael Yachnis (1,2)	Naval Facilities Engineering Command

* denotes Chairman

The original report has received numerous comments since its original publication in 1981. Some of these were comments from interested individuals or organizations while others accompanied the ICSSC ballots. This document has incorporated as many of these comments as possible.

The work of the committee members, many of whom contributed considerable effort, and the reviewers is appreciated.

SI Conversion Units

The following list of conversion factors for the most frequently used quantities in building design and construction may be used.

QUANTITY	INTERNATIONAL (SI) UNIT	U.S. CUSTOMARY UNIT	APPROXIMATE CONVERSION	
LENGTH	meter (m)	foot (ft)	1 m	= 3.2808 ft
	millimeter (mm)	inch (in)	1 mm	= 0.0394 in
AREA	square meter (m^2)	square yard (yd^2)	1 m^2	= 1.1960 yd^2
		square foot (ft^2)	1 m^2	= 10.764 ft^2
	square millimeter (mm^2)	square inch (in^2)	1 mm^2	= 1.55 x 10^{-3} in^2
VOLUME	cubic meter (m^3)	cubic yard (yd^3)	1 m^3	= 1.3080 yd^3
		cubic foot (ft^3)	1 m^3	= 35.315 ft^3
	cubic millimeter (mm^3)	cubic inch (in^3)	1 mm^3	= 61.024 x 10^{-6} in^3
CAPACITY	liter (L)	gallon (gal)	1 L	= 0.2642 gal
	milliliter (mL)	fluid ounce (fl oz)	1 mL	= 0.0338 fl oz
VELOCITY, SPEED	meter per second (m/s)	foot per second (ft/s or f.p.s.)	1 m/s	= 3.2808 ft/s
	kilometer per hour (km/h)	mile per hour (mile/h or m.p.h.)	1 km/h	= 0.6214 mile/h
ACCELERATION	meter per second squared (m/s^2)	foot per second squared (ft/s^2)	1 m/s^2	= 3.2808 ft/s^2
MASS	metric ton (t) [1000 kg]	short ton [2000 lb]	1 t	= 1.1023 ton
	kilogram (kg)	pound (lb)	1 kg	= 2.2046 lb
	gram (g)	ounce (oz)	1 g	= 0.0353 oz
DENSITY	metric ton per cubic meter (t/m^3)	ton per cubic yard (ton/yd^3)	1 t/m^3	= 0.8428 ton/yd^3
	kilogram per cubic meter (kg/m^3)	pound per cubic foot (lb/ft^3)	1 kg/m^3	= 0.0624 lb/ft^3
FORCE	kilonewton (kN)	ton-force (tonf)	1 kN	= 0.1124 tonf
		kip [1000 lbf]	1 kN	= 0.2248 kip
	newton (N)	pound-force (lbf)	1 N	= 0.2248 lbf
MOMENT OF FORCE, TORQUE	kilonewton meter (kN·m)	ton-force foot (tonf·ft)	1 kN·m	= 0.3688 tonf·ft
	newton meter (N·m)	pound-force inch (lbf·in)	1 N·m	= 8.8508 lbf·in
PRESSURE, STRESS	megapascal (MPa)	ton-force per square inch (tonf/in^2)	1 MPa	= 0.0725 tonf/in^2
		ton-force per square foot (tonf/ft^2)	1 MPa	= 10.443 tonf/ft^2
	kilopascal (kPa)	pound-force per square inch (lbf/in^2)	1 kPa	= 0.1450 lbf/in^2
		pound-force per square foot (lbf/ft^2)	1 kPa	= 20.885 lbf/ft^2
WORK, ENERGY, QUANTITY OF HEAT	megajoule (MJ)	kilowatthour (kWh)	1 MJ	= 0.2778 kWh
	kilojoule (kJ)	British thermal unit (Btu)	1 kJ	= 0.9478 Btu
	joule (J)	foot pound-force (ft·lbf)	1 J	= 0.7376 ft·lbf
POWER, HEAT FLOW RATE	kilowatt (kW)	horsepower (hp)	1 kW	= 1.3410 hp
	watt (W)	British thermal unit per hour (Btu/h)	1 W	= 3.4121 Btu/h
		foot pound-force per second (ft·lbf/s)	1 W	= 0.7376 ft·lbf/s
COEFFICIENT OF HEAT TRANSFER (U-value)	watt per square meter kelvin (W/m^2·K) [=(W/m^2·°C)]	Btu per square foot hour degree Fahrenheit (Btu/ft^2·h·°F)	1 W/m^2·K	= 0.1761 Btu/ft^2·h·°F
THERMAL CONDUCTIVITY [k-value]	watt per meter kelvin (W/m·K) [=(W/m·°C)]	Btu per square foot degree Fahrenheit (Btu/ft^2·°F)	1 W/m·K	= 0.5778 Btu/ft^2·°F

NOTES: (1) The above conversion factors are shown to three or four places of decimals.

(2) Unprefixed SI units are underlined. (The kilogram, although prefixed, is an SI base unit.)

REFERENCES:

NBS Guidelines for the Use of the Metric System, LC1056, Revised August 1977;
The Metric System of Measurement, Federal Register Notice of October 26, 1977, LC 1078, Revised November 1977;
NBS Special Publication 330, "The International System of Units (SI)," 1977 Edition;
NBS Technical Note 938, "Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction," Revised edition June 1977;
ASTM Standard E621-78, "Standard Practice for the Use of Metric (SI) Units in Building Design and Construction," (based on NBS TN 938), March 1978;
ANSI Z210.1-1976, "American National Standard for Metric Practice."
ASTM E380-79$^{\epsilon}$, "Standard for Metric Practice."
IEEE Std. 268-1979, "Standard for Metric Practice."

SEISMIC DESIGN GUIDELINES FOR FEDERAL BUILDINGS

ABSTRACT

This document has been prepared as a coordinated adaptation of existing voluntary standards, model building codes, Federal regulations, and research reports for use by Federal agencies. The technical content is similar to the seismic requirements of the 1985 **Uniform Building Code** (UBC). However, there are instances of substantive difference from the UBC. Several important provisions have been incorporated from other sources considered in this adaptation. For example, the seismic zone map is the one in current use in ANSI A58.1-1982 **Minimum Design Loads for Buildings and Other Structures**. A number of provisions have been added to these guidelines that are based on the current practices and policies of various Federal agencies. Furthermore, in the spirit of improvement, this document is organized considerably differently from the UBC and many provisions are phrased differently.

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SEISMIC DESIGN GUIDELINES FOR FEDERAL BUILDINGS

- PROVISIONS -

1. REGULATION

1.1 SCOPE

These guidelines are for use in the planning, design, and construction of new buildings and their appurtenances and in the alteration, repair, or change of use of existing buildings. The guidelines are intended to provide appropriately varying degrees of safety of buildings against the effects of seismic ground shaking.

1.2 DEFINITIONS

The following definitions apply to the terms used in this document.

APPROVED, as to materials and types of construction, refers to approval by the designated authority as the result of investigation and tests conducted by him, or by reason of accepted principles or tests by national authorities, technical or scientific organizations.

BASE OF STRUCTURE is the level at which the earthquake motions are assumed to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported. This level does not necessarily coincide with the ground level.

BEARING WALL is any wall meeting either of the following classifications:

(1) Any metal or wood stud wall which supports more than 100 pounds per lineal foot of superimposed load.

(2) Any masonry or concrete wall which supports more than 200 pounds per lineal foot of superimposed load, or any such wall supporting its own weight for more than one story.

BOX SYSTEM is a system in which a significant fraction of the gravity load is supported on bearing walls. Also see Sections 3.1.2 and 3.1.3.

BRACED FRAME is a truss system or its equivalent which is provided to resist lateral seismic forces in the frame system and in which the members are subjected primarily to axial stresses by the seismic forces.

BUILDING is any structure used or intended for supporting or sheltering any human use or occupancy.

DEAD LOAD is the vertical load due to the weight of all permanent structural and nonstructural components of a building, such as walls, floors, roofs, and fixed service equipment.

DESIGNATED AUTHORITY is the official representative of the government who is charged with the administration and enforcement of these guidelines, or his duly authorized representative.

DIAPHRAGM is a horizontal, or nearly horizontal, component or system, including bracing systems, that is designed to transmit lateral seismic forces to the vertical elements of the seismic force-resisting system.

DUAL SYSTEM is a system in which essentially all the total gravity load is supported on framing without the use of bearing walls and in which the designated seismic force-resisting system in the direction under consideration is composed of a combination of reinforced concrete or structural steel ductile moment-resisting space frames with shear walls or braced frames. Also see Sections 3.1.2 and 3.1.3.

DUCTILE MOMENT-RESISTING SPACE FRAME is a moment-resisting space frame with special ductility provisions to permit repeated inelastic straining.

DUCTILE MOMENT-RESISTING SPACE FRAME SYSTEM is a system in which essentially all the gravity load is supported on framing without the use of bearing walls and in which the designated seismic force-resisting system in the direction under consideration is composed entirely of reinforced concrete or structural steel ductile moment-resisting space frames (unbraced frames). Also see Sections 3.1.2 and 3.1.3.

ESSENTIAL FACILITIES are those buildings or their appurtenances which must be safe and usable for emergency purposes after a major earthquake in order to preserve the health and safety of the general public. Also see Section 1.4.2 and Table 1.2. Such facilities shall include but not be limited to:

(1) Hospitals and other medical facilities having surgery or emergency treatment areas

(2) Fire and police stations

(3) Government disaster operation and communication centers deemed to be vital in emergencies

(4) Power stations and other utilities required as emergency facilities

EXTERIOR WALL is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane.

HEIGHT is the vertical distance from the base to uppermost level in the structure unless otherwise indicated.

HIGH RISK FACILITIES are those buildings where the primary occupancy is for assembly use for more than 300 persons, or where the occupants' mobility is restricted or impaired, or where the contents of the building are hazardous. Also see Section 1.4.2 and Table 4.1.

LIVE LOAD is the load superimposed by the use and occupancy of the building not including the wind load, earthquake load, or dead load.

MOMENT-RESISTING SPACE FRAME for lateral forces is an unbraced vertical load-carrying space frame in which members are restrained at the joints and arranged so that they are subjected primarily to flexural stresses.

PARAPET WALL is that part of any wall entirely above the roof line.

SEISMIC FORCE-RESISTING SYSTEM is that part of the structural system assigned to resist seismic forces.

SHEAR WALL is a wall designed to resist lateral forces parallel to the wall.

SPACE FRAME is a three-dimensional structural system without bearing walls, composed of interconnected members laterally supported so as to function as a complete self-contained unit with or without the aid of a horizontal diaphragms or floor-bracing systems.

> **MOMENT-RESISTING SPACE FRAME** for lateral forces is an unbraced vertical load-carrying space frame in which members are restrained at the joints and arranged so that they are subjected primarily to flexural stresses. (This definition is repeated here for clarity.)

DUCTILE MOMENT-RESISTING SPACE FRAME is a moment-resisting space frame with special ductility provisions to permit repeated inelastic straining. (This definition is repeated here for clarity.)

STRUCTURE is that which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner.

1.3 NOTATION

The following notations are used in these guidelines.

C = Numerical coefficient for the vibratory response of a structure to seismic motions, as specified in Section 4.2.1.

$\bar{C}$ = Value of C used in calculating a lower limit for the base shear, as specified in Section 4.3.3.

C_m = Value of C for the m^{th} specific mode of vibration, as specified in Section 4.3.2.

C_p = Numerical coefficient for the vibratory response of a part of a structure to seismic motions, as specfied in Section 4.5.

D = The dimension of the structure, in feet, in a direction parallel to the applied forces.

F_i, F_n, F_x = Lateral seismic force applied to level i, n, or x, respectively.

F_p = Lateral seismic forces on a part of the structure and in the direction under consideration.

F_t = That portion of V considered concentrated at the top of the structure in addition to F_n as specified in Section 4.2.4.

F_{xm} = Lateral seismic force applied to level x when considering the m^{th} mode of vibration.

f_i = Distributed portion of total lateral force at level i for use in determining the period of vibration, T, in Equation 4.5.

g = Acceleration due to gravity

h_i, h_n, h_x = Height in feet above the base to level i, n, or x, respectively.

I = Numerical coefficient for occupancy hazard, as specified in Section 1.4.2 and Table 1.4.

K = Numerical coefficient for structural system response to seismic motions, as specified in Sections 3.1.2 and 3.1.3.

Level i = Level of the structure referred to by the subscript i; $i = 1$ designates the first level above the base.

Level n = That level which is uppermost in the main portion of the structure.

Level x = That level which is under design consideration; $x = 1$ designates the first level above the base.

M_{xm} = Overturning moment at level x when considering the m^{th} mode of vibration.

N = The total number of stories above the base to level n.

S = Numerical coefficient for site-structure resonance in response to seismic motions, as specified in Section 4.2.3.

T = Fundamental elastic period of vibration of the building or structure in seconds in the direction under consideration.

$\bar{T}$ = Value of T used in calculating a lower limit for the base shear.

T_m = Period of vibration for the m^{th} mode, in seconds.

T_s = Characteristic site period.

V = The total lateral seismic force or shear at the base.

$\bar{V}$ = A lower limit of V when using modal analysis.

V_m = The value of V when considering the m^{th} mode of vibration.

V_t = The total lateral seismic force or shear at the base determined by means of modal analysis.

V_{xm} = The total lateral seismic force at level x when considering the m^{th} mode of vibration.

W = The total dead load including the partition loading where applicable; see Section 4.2.1.

W_m = The portion of W effective for the m^{th} mode of vibration.

w_i, w_x = That portion of W which is located at or is assigned to level i or x, respectively.

W_p = The weight of a portion of a structure or nonstructural component.

Z = Numerical coefficient for the seismic hazard zone, as specified in Section 4.2.1 and determined by Figures 1.1 and 1.2. For locations in Zone No. 1, Z = 3/16. For locations in Zone No. 2, Z = 3/8. For locations in Zone No. 3, Z = 3/4. For locations in Zone No. 4, Z = 1.

δ_i = Deflection at level i relative to the base, due to applied lateral seismic forces, f_i used in determining the period of vibration, T.

ϕ_{im}, ϕ_{xm} = The displacement amplitude at level i, or x, of the building for the fixed-based condition when vibrating in its m^{th} mode.

1.4 HAZARD CLASSIFICATIONS

1.4.1 Seismic Ground Shaking Hazard

The zone representing the level of seismic ground shaking hazard shall be established for each building site according to the maps shown in Figure 1.1. For locations not included in Figure 1.1, the zone shall be established from approved documents or from a site evaluation as indicated in the following paragraph.

For those building sites that have had a design ground acceleration established by means of an approved site evaluation (refer to Section 2.2.1), the zone shall be determined according to Table 1.1 for use in these guidelines where a zone is required.

1.4.2 Occupancy Hazard

The occupancy of the building shall be classified and the occupancy importance factor I shall be established for each building according to Table 1.2, unless otherwise specified by the designated authority.

1.5 ALTERNATIVE PROVISIONS

Alternate materials, methods of construction, structural concepts, and analytical procedures to those prescribed in this standard may be used subject to the approval of the designated authority. Substantiating evidence demonstrating that the proposed alternate, for the purpose intended, will be at least equal in strength, durability, seismic resistance, validity, and safety shall be submitted.

TABLE 1.1 - ZONE FOR SITES WITH APPROVED SITE EVALUATION

Design ground acceleration, a	Zone
$a < 0.05g$	0
$0.05g \leq a < 0.10g$	1
$0.10g \leq a < 0.20g$	2
$0.20g \leq a < 0.40g$	3
$0.40g \leq a$	4

TABLE 1.2 - VALUES FOR OCCUPANCY IMPORTANCE FACTOR

Type of Occupancy	I
Essential Facilitites. Essential facilities are those buildings or their appurtenances which must be safe and usable for emergency purposes after a major earthquake in order to preserve the health and safety of the general public. Such facilities shall include but not be limited to: 1. Hospitals and other medical facilities having surgery or emergency treatment areas 2. Fire and police stations 3. Government disaster operation and communication centers deemed to be vital in emergencies 4. Power stations and other utilities required as emergency facilities	1.5
High Risk Facility. Any building where the primary occupancy is for assembly use for more than 300 persons, or where the occupants' mobility is restricted or impaired, or where the contents of the building are hazardous	1.25
All Other.	1.0

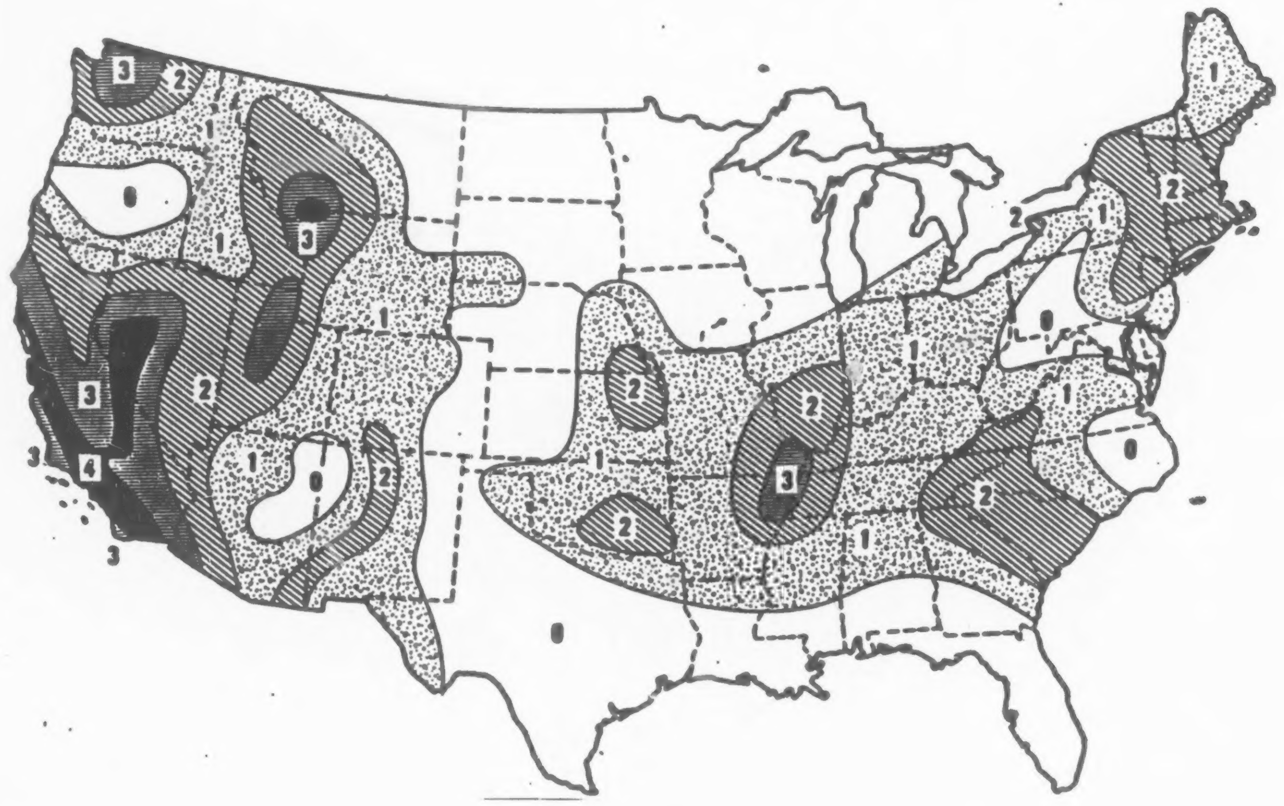
3
2
1
0
1
3
2
3
3
4
3
1
0
2
1
2
1
2
3
2
1
1
1
2
0
0
1
2
1
1
2
0

FIGURE 1.1 SEISMIC ZONE MAP

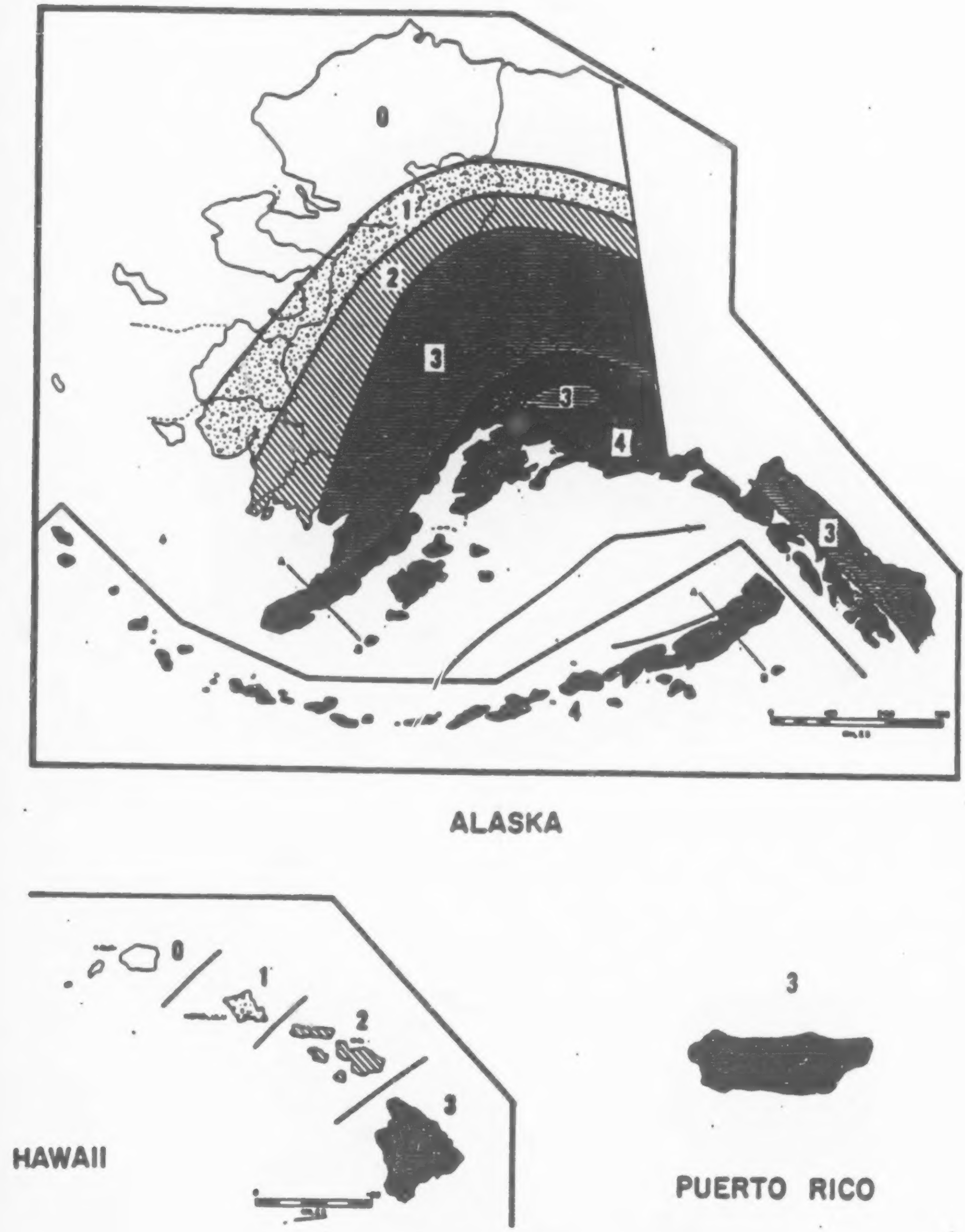
0
1
2
3
3
4
3
4
ALASKA
0
1
2
3
HAWAII
3
PUERTO RICO

FIGURE 1.2 SEISMIC ZONE MAP

2. GENERAL REQUIREMENTS

2.1 GENERAL PERFORMANCE REQUIREMENT

Every building and the appurtenances and parts thereof shall be designed and constructed to resist the forces produced by seismic ground shaking as provided in these guidelines except as may be specified by the designated authority. Buildings located in zone 0 are exempt from the requirements in these guidelines.

2.2 SITE PLANNING FOR NEW BUILDINGS

2.2.1 Site Evaluation Study

A site evaluation study shall be conducted for all hospitals in zones 3 or 4 and other buildings specified by the designated authority. The study shall establish the design ground motion for the site and shall evaluate the likelihood and effect of the following phenomena:

(1) surface rupture due to active fault displacement

(2) liquefaction

(3) landslide or slope stability failure

(4) subsidence

2.2.2 Site Limitations

This section applies only to those buildings for which a site evaluation study is required. Essential Facilities shall not be sited such that surface rupture due to fault displacement would pass through the building. For sites that have a potential for liquefaction, landslide, or subsidence, the building, foundation, and/or subsoil shall be engineered to mitigate the hazard or the effects of the phenomena.

2.3 DESIGN OF NEW BUILDINGS

2.3.1 Application of the Provisions

The structural portion of the building shall be designed to satisfy the requirments of Chapter 3, STRUCTURAL DESIGN CRITERIA. For all buildings in Zones 3 or 4 and buildings with an Importance Factor I greater than 1.0 in Zone 2, the nonstructural portion of the building shall be designed to satisfy the requirements of Chapter 7, NONSTRUCTURAL DESIGN REQUIREMENTS.

2.3.2 Documentation

Drawings, specifications, basis of design, calculations, reports, certifications, and other substantiation necessary to verify compliance with the design provisions shall be submitted to the designated authority.

2.4 CONSTRUCTION

The construction quality of all buildings in Zones 3 or 4 and buildings with an Importance Factor I greater than 1.0 in Zone 2 shall be assured by satisfying the requirements of Chapter 8, CONSTRUCTION QUALITY CONTROL.

2.5 EXISTING BUILDINGS

2.5.1 Alterations and Repairs

When specified by the designated authority any Federal building for which the cost of renovations or repairs, exclusive of seismic strengthening, exceeds 50 percent of the replacement cost of the improved building, it must be corrected to resist the appropriate level of earthquake forces.

Minor structural alterations may be made in existing buildings and other structures, but the resistance to lateral seismic forces shall be not less than that before such alterations were made, unless the building as altered meets the requirements of these guidelines.

2.5.2 Changes of Use or Location

Changes of use that increase the occupancy importance factor I, or of location that increase the seismic hazard zone shall be permitted only if the building is made to satisfy the requirements of this standard.

3. STRUCTURAL DESIGN CRITERIA

3.1 SEISMIC FORCE-RESISTING SYSTEMS

3.1.1 Integrity

The seismic force-resisting system shall include a continuous load path, or paths, to transfer all seismic forces to the final point of resistance. Connections and elements shall be provided to transfer the seismic forces from other parts of the building to the seismic force-resisting system, using the forces specified in Section 4.5 and Section 7.1, where applicable.

3.1.2 System Response Classification

Each building shall be assigned to one of the following categories based on the type of elements used to support gravity loads and on the type and ductility of elements designated to be the seismic force-resisting system:

DUCTILE MOMENT-RESISTING SPACE FRAME SYSTEM (K = 0.67)

A system in which essentially all the gravity load is supported on framing without the use of bearing walls and in which the designated seismic force-resisting system in the direction under consideration is composed entirely of reinforced concrete or structural steel ductile moment-resisting space frames (unbraced frames).

DUAL SYSTEM (K = 0.80)

A system in which essentially all the total gravity load is supported on framing without the use of bearing walls and in which the designated seismic force-resisting system in the direction under consideration is composed of a combination of reinforced concrete or structural steel ductile moment-resisting space frames with shear walls or braced frames.

BOX SYSTEM (K = 1.33)

A system in which a significant fraction of the gravity load is supported on bearing walls.

BUILDING FRAME SYSTEM (K = 1.0)

Any other structural system.

Rigid elements that are not designated as part of the seismic force-resisting system may be incorporated into buildings provided that their effect on the action of the seismic force-resisting system is considered and provided for in the design. In particular, moment-resisting space frames and ductile moment-resisting space frames may be enclosed by or adjoined by other rigid elements if it can be shown that the action or failure of the other rigid elements will not impair the vertical and lateral load resisting ability of the space frame.

Structural steel ductile moment-resisting space frames shall satisfy the ductility provisions of Section 6.2, and reinforced concrete ductile moment-resisting space frames shall satisfy the ductility provisions of Section 6.3.

3.1.3 Strength

Members and connections shall resist the effect of combined gravity and seismic forces. The resistance shall be determined according to Chapter 5, DESIGN AND CONSTRUCTION STANDARDS FOR STRUCTURAL MATERIALS. In computing the effect of seismic force in combination with vertical loads, gravity load stresses induced in members by dead load plus design live load and snow load, except roof live load, shall be considered. Consideration shall also be given to minimum gravity loads acting in combination with seismic forces.

In addition, the following special requirements apply to the ductile moment-resisting space frame system and the dual system:

DUCTILE MOMENT-RESISTING SPACE FRAME SYSTEM (K = 0.67)

The ductile moment-resisting space frames shall have the capacity to resist the total required lateral seismic force by themselves.

DUAL SYSTEMS (K = 0.80)

(a) The frames and shear walls or braced frames shall resist the total lateral force in accordance with their relative rigidities considering the interaction of the shear walls and frames.

(b) The shear walls or braced frames acting independently of the ductile moment-resisting portions of the space frame shall resist the total required seismic forces.

(c) The ductile moment-resisting space frame shall have the capacity to resist not less than 25 percent of the total required lateral seismic force.

3.1.4 Stiffness and Building Separations

Lateral deflections or drift of each story relative to its adjacent stories due to seismic forces as determined in Section 4.4.7 shall not exceed 0.015 times the story height, unless it can be demonstrated that greater drift can be tolerated. Diaphragm deformations shall be considered in the design of the supported walls.

All portions of structures shall be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally to avoid contact under deflection from seismic action.

3.1.5 Overturning Stability

Every building shall be designed to resist the overturning effects caused by the seismic forces specified in this standard.

3.1.6 Height

All buildings in zones 3 or 4 and buildings with an importance factor I greater than 1.0 in zone 2 that are more than 160 feet in height shall have ductile moment-resisting space frames capable of resisting not less than 25 percent of the required seismic forces for the structure as a whole.

3.2 OTHER STRUCTURAL ELEMENTS

3.2.1 Strength and Anchorage

Structural elements and their anchorages shall resist the seismic forces induced by their own mass and by connected elements, as determined in Section 4.6.1. Resistance shall be determined in accordance with chapter 5, DESIGN AND CONSTRUCTION STANDARDS FOR STRUCTURAL MATERIALS.

3.2.2 Compatibility

For all buildings in Zones 3 or 4 and buildings with an importance factor I greater than 1.0 in Zone 2, all framing elements not required by design to be part of the seismic force-resisting system shall be investigated and shown to be adequate for vertical load-carrying capacity and induced moment due to the force effects of the distortions calculated according to Section 4.4.7. The rigidity of other elements shall be considered in accordance with Section 4.4.1.

3.3 FOUNDATIONS

3.3.1 Soil and Foundation Capacity

In the determination of the foundation design criteria, recognition shall be given to the dynamic nature of the forces, the expected ground motions, and the design basis for strength and ductility of the structure.

3.3.2 Structural Ductility

For all buildings in Zones 3 or 4 and buildings with an Importance Factor I greater than 1.0 in Zone 2 that have a dual system or a ductile moment-resisting space frame system, the special ductility requirements for structural steel or reinforced concrete specified in Sections 6.2 and 6.3 shall apply to all structural elements below the base which are required to transmit forces to the foundation resulting from the application of the design lateral seismic forces to the building.

4. STRUCTURAL ANALYSIS PROCEDURES

Stresses shall be calculated as the effect of a force applied horizontally at each floor and roof level above the base. The force shall be assumed to come from any horizontal direction; buildings shall be analyzed for the force on each principal axis.

4.1 REQUIRED METHOD FOR SEISMIC-RESISTING SYSTEMS

The seismic loads for all buildings shall be analyzed according to Section 4.2, as a minimum, except for the following buildings, which shall be analyzed according to Section 4.3 as a minimum:

(1) buildings specified by the designated authority

(2) hospitals in Zones 3 or 4 that have shapes or framing systems irregular in a vertical sense

(3) buildings over 4 stories in Zone 4 that have shapes or framing systems irregular in a vertical sense.

For buildings with irregular shapes or framing systems in a horizontal sense, special attention should be given to the distribution of forces; the designated authority may require the use of a more sophisticated analysis for such buildings.

The designated authority may require or approve the use of a soil-structure interaction analysis that will modify the seismic forces and displacements determined in this chapter. The seismic load effects shall be analyzed according to Section 4.4.

4.2 ELASTIC STATIC LOAD ANALYSIS

4.2.1 Base Shear

The total lateral seismic force assumed to act at the base of the structure shall be determined as follows for each main axis:

$$V = ZIKCSW \qquad \text{(Eq. 4.1)}$$

where the terms are as follows:

Z - Shall be determined from Table 4.1 for buildings that do not have an approved site evaluation. For buildings that have a design ground acceleration established according to an approved site evaluation study, Z = 2.5 times the design ground acceleration (see Section 2.2.1) expressed as a fraction of the acceleration of gravity.

I - As specified in Section 1.4.2

C - Shall be determined by Equation 4.2 as

$$C = \frac{1}{15\sqrt{T}} \qquad \text{(Eq. 4.2)}$$

The value of C need not exceed 0.12. The value of T is specified in Section 4.2.2.

S - Shall be determined in accordance with Section 4.2.3, except that the product CS need not exceed 0.14.

K - Shall be determined from Table 4.2 for buildings. For other structures and appurtenances associated with buildings K shall be determined from Table 4.3.

For elevated tanks, the minimum value of KC shall be 0.12 and the maximum value of KCS need not exceed 0.30. Elevated tanks which are supported by buildings or are not supported on four or more cross-braced legs as described above shall be designed in accordance with Section 4.5, using $C_p = 0.3$.

W - Shall be equal to the total dead load. For storage and warehouse occupancies, 25 percent of the floor live load shall be included in W. Where the design snow load is 30 psf or less, no part need be included in the value of W. Where the snow load is greater than 30 psf, the snow load shall be included; however, the snow load may be reduced by up to 75 percent, where the snow load duration warrants and the designated authority approves the reduction.

4.2.2 Period of Vibration

The period T shall be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis, which could make use of an equation such as:

$$T = 2\pi\sqrt{(\sum_{i=1}^{n} w_i \delta_i^2)} \quad (g\sum_{i=1}^{n} f_i \delta_i) \qquad \text{(Eq.4.5)}$$

where the values of f_i represent any lateral force distributed approximately in accordance with the principles of Section 4.2.4

or any other rational distribution. The elastic deflections, i, shall be calculated using the applied lateral forces, f_i. The value of T so determined shall not exceed the value calculated by the appropriate choice Equation 4.3 or 4.4 below by more than 20 percent.

In the absence of a determination as indicated above, the value of T for buildings may be determined as:

$$T = \frac{0.05hn}{\sqrt{D}} \qquad \text{(Eq. 4.3)}$$

or in buildings in which the lateral force-resisting system consists of ductile moment-resisting space frames capable of resisting 100 percent of the required lateral forces and such system is not enclosed by or adjoined by more rigid elements tending to prevent the frame from resisting lateral forces:

$$T = 0.10N \qquad \text{(Eq.4.4)}$$

where N is the total number of stories above the base.

4.2.3 Site Coefficient

The value of S shall be determined by one of the following two methods.

Method A

The value of S shall be determined by the following equations, but shall not be less than 1.0:

For $T/T_s \leq 1.0$

$$S = 1.0 + (T/T_s) - 0.5\,(T/T_s)^2 \qquad \text{(Eq.4.6)}$$

For $T/T_s >$ than 1.0

$$S = 1.2 + 0.6\,(T/T_s) - 0.3\,(T/T_s)^2 \qquad \text{(Eq. 4.7)}$$

The period T in Equations 4.6 and 4.7 shall be as determined in Section 4.2.2 but T shall not be less than 0.3 second.

The range of values of T_s may be established from properly substantiated geotechnical data, except that Ts shall not be taken as less than 0.5 second nor more than 2.5 seconds. T_s shall be that value within the range of site periods, as determined above, that is nearest to T.

When T_s is not properly established, the value of S shall be 1.5.

Exception:

Where T has been established by a properly substantiated analysis and exceeds 2.5 seconds, the value of S may be determined by assuming a value of 2.5 seconds for T_s.

Method B

The effects of site conditions on building response shall be established based on soil profile types defined as follows:

(1) Soil Profile Type 1 is a profile with:

(a) rock of any characteristic, either shale-like or crystalline in nature. Such material may be characterized by a shear wave velocity greater than 2,500 feet per second; or,

(b) stiff soil conditions where the soil depth is less than 200 feet and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

(2) Soil Profile Type 2 is a profile with deep cohesionless or stiff clay conditions, including sites where the soil depth exceeds 200 feet and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

(3) Soil Profile Type 3 is a profile with soft to medium-stiff clays and sands, characterized by 30 feet or more of soft to medium-stiff clays with or without intervening layers of sand or other cohesionless soils.

In locations where the soil properties are not known in sufficient detail to determine the soil profile type or where the profile does not fit any of the three types, Soil Profile Type 3 shall be used. The coefficient S for the effects of site conditions on building response is given in Table 4.4.

4.2.4 Vertical Distribution of Forces

(A) Structures having irregular shapes or framing systems

The distribution of the seismic lateral forces in structures which have highly irregular shapes, large differences in lateral resistance or stiffness between adjacent stories, or other unusual structural features, shall be determined considering the dynamic characteristics of the structure.

Buildings having setbacks wherein the plan dimension of the tower in each direction is at least 75 percent of the corresponding plan dimension of the lower part may be considered as uniform buildings without setbacks for the purpose of this section, provided other irregularities do not exist.

(B) Structure having regular shapes or framing systems

The total lateral force V shall be distributed over the height of the structure as follows:

$$V = F_t + \sum_{i=1}^{n} F_i \qquad \text{(Eq.4.8)}$$

The concentrated force at the top shall be determined as:

$$F_t = 0.07TV \qquad \text{(Eq. 4.9)}$$

F_t need not exceed 0.25V and may be considered as zero where T is 0.7 second or less. The remaining portion of the total base shear V shall be distributed over the height of the structure, including level n, as follows:

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad \text{(Eq. 4.10)}$$

4.3 ELASTIC DYNAMIC LOAD ANALYSIS

The lateral seismic forces shall be determined in accordance with this section using all modes of vibration with a period greater than 0.04 second, but in no case less than the first three modes in either principal direction.

4.3.1 Mode Shapes and Periods

The mode shape, ϕ_{im}, and the modal period, T_m shall be determined for each mode in accordance with the principles of mechanics.

4.3.2 Modal Base Shear

The total lateral seismic force for a mode shall be determined as follows:

$$V_m = ZIKC_mSW_m \tag{Eq. 4.12}$$

where

Z, I, K and S are as defined in Section 4.2

C_m shall be determined for each mode as:

$$C_m = \frac{1}{15\sqrt{T_m}} \tag{Eq. 4.13}$$

The value of C_m need not exceed 0.12 and the product of C_mS need not exceed 0.14. T_m is the period of vibration for the m^{th} mode, in seconds. Subject to the approval of the designated authority, a site specific spectral shape may be used in lieu of Eq. 13.

W_m shall be determined for each mode as:

$$W_m = \frac{\left(\sum_{i=1}^{n} w_i\phi_{im}\right)^2}{\sum_{i=1}^{n} w_i\phi_{im}^2} \tag{Eq. 4.14}$$

4.3.3 Design Values

The following quantities shall be determined for each mode according to the principles of mechanics:

(1) F_{xm} - the equivalent lateral seismic force applied to each level

(2) ϕ_{xm} - the lateral displacement at each level

(3) V_{xm} - the lateral seismic shear force at each level

(4) M_{xm} - the overturning moment at each level

(5) the story drift at each level

The total value for each of the above quantities and the total base shear V_t shall not be less than that obtained as the square root of the sum of the squares of the quantity for each mode. V_t shall be compared with the quantity V, where

$\bar{V}$ is determined from Equation 4.1 by substituting $\bar{C}$ for C

$\bar{C}$ is determined from Equation 4.2 by substituting $\bar{T}$ for T

$\bar{T}$ is determined as 1.4 times the value determined for T in Equation 4.3 or 4.4, as appropriate.

Where V_t is less than V, the design value for each quantity shall be the product of the total value and the following factor, A:

$$\bar{A} = V/V_t \qquad \text{(Eq. 4.15)}$$

V_t need not exceed $\bar{V}$ determined from Equation 4.1.

The value of base shear shall not be less than 90 per cent of that computed by Equation 4.1.

4.4 ELASTIC LOAD EFFECT ANALYSIS

4.4.1 Shear

Total shear in any horizontal plane shall be distributed to the various elements of the seismic force-resisting system in proportion to their rigidities considering the total rigidity of the horizontal bracing system or diaphragm.

4.4.2 Horizontal Torsion

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution on that level.

Provisions shall be made for the increase in shear resulting from the horizontal torsion due to an eccentricity between the center of mass and the center of rigidity. Negative torsional shears shall be neglected. Where the vertical resisting elements depend on diaphragm action for shear distribution at any level, the shear-resisting elements shall be capable of resisting a torsional moment assumed to be equivalent to the story shear acting with an eccentricity of not less than 5 percent of the maximum building dimension at that level.

4.4.3 Diaphragm Forces

Floor and roof diaphragms shall be designed to resist the effects of forces determined as follows:

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=1}^{n} w_i} w_{px} \qquad \text{(Eq. 4.16)}$$

where

F_i = the lateral force applied to level i

w_i = the portion of W at level i

w_{px} = the weight of the diaphragm and the elements tributary thereto at level x, including 25 percent of the floor live load in storage and warehouse occupancies.

The force F_{px} determined from Equation 4.16 need not exceed $0.30(ZIw_{px})$.

When the diaphragm is required to transfer lateral forces from the vertical resisting elements above the diaphragm to other vertical resisting elements below the diaphragm due to offsets in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Equation 4.16.

However, in no case shall lateral force on the diaphragm be less than $0.14(ZIw_{px})$.

4.4.4 Overturning

At any level the incremental changes of the design overturning moment in the story under consideration shall be distributed to the various resisting elements in the same proportion as the distribution of shears in the resisting system.

Where other vertical members are provided which are capable of partially resisting the overturning moments, a redistribution may be made to these members if framing members of sufficient strength and stiffness to transmit the required loads are provided.

Where a vertical resisting element is discontinuous, the overturning moment carried by the lowest story of that element shall be carried down as loads to the foundation.

4.4.5 Orthogonal Effect

For all buildings in Zones 1 or 2, the design seismic load effects may be determined assuming separate application of the seismic loads on each of the main axes of the structure. For all buildings in Zones 3 or 4, the seismic load effect shall be determined from the most critical direction of application of the seismic loads, which may be assumed to be satisfied if the following combination is taken: 100 percent of the force effect for one direction of motion plus 30 percent of the force effect for the perpendicular direction of motion. The combination requiring the maximum element strength shall be used.

Exception:

Diaphragms, and components of the seismic force-resisting system utilized in only one of the two orthogonal directions need not be designed for the combined effects.

4.4.6 Vertical Motion Effect

For horizontal cantilever components and prestressed members, a vertical acceleratioin equal to one-half of the horizontal accerleratioin must be considered in design.

4.4.7 Displacements

The displacement calculated from the application of the required lateral forces shall be multiplied by (3.0/K) to obtain the design displacement (and drift). The ratio (3.0/K) shall not be less than 3.0.

4.5 ANALYSIS OF OTHER STRUCTURAL ELEMENTS

Parts or portions of structures, nonstructural components and their anchorage to the main structural system shall resist the following lateral seismic forces:

$$F_p = ZIC_pW_p \qquad \text{(Eq. 4.17)}$$

where

Z and I are the coefficients used for the building (see Section 4.2.1 and Section 1.4.2)

W_p is the weight of the part or portion

C_p is set forth in Table 4.5.

Interconnection forces between two parts of the structure shall not be less than $0.133ZI$ times the weight of the smaller portion.

TABLE 4.1 - ZONE COEFFICIENT

Zone	Z
4	1
3	3/4
2	3/8
1	3/16
0	0

TABLE 4.2 - K FOR BUILDINGS

System Response Classification (see 3.1.2)	K
Ductile Moment-Resisting Space Frame	0.67
Dual System	0.80
Box System	1.33
Building Frame System	1.0

TABLE 4.3 - K FOR OTHER STRUCTURES

Type of Structure	K
Elevated tanks plus full contents, on four or more cross-braced legs and not supported by a building	2.5
Structures other than buildings and other than those set forth in 4.6.1	2.00

TABLE 4.4 - SITE COEFFICIENT

Soil Profile Type	S
1	1.0
2	1.2
3	1.5

TABLE 4.5 - HORIZONTAL FORCE FACTOR C_p FOR ELEMENTS OF STRUCTURES

Part or Portion of Buildings	Direction of Horizontal Forces	Value of C_p
Exterior bearing and nonbearing walls, interior bearing walls and partitions, interior non-bearing walls and partitions. Masonry or concrete fences over 6 feet high.	Normal to flat surface	0.3
Cantilever elements, chimneys or stacks	Any direction	0.8
Connections for prefabricated structural elements other than walls, with force applied at center of gravity of assembly.	Any direction	0.3

5. DESIGN AND CONSTRUCTION STANDARDS FOR STRUCTURAL MATERIALS

This chapter specifies the commonly accepted standards for materials, design, and construction that are presumed as a basis for this standard. The designated authority may require or approve the use of a different edition or standard than specified here. In overseas construction, where local materials of grades other than those herein are used, the working stresses, grades, and other requirements of this standard shall be modified as applicable in accordance with good engineering practice.

5.1 STEEL

The quality and testing of steel materials and the design and construction of steel components which resist seismic forces shall conform to the following references, except as modified by other provisions of this standard.

(1) Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, American Institute of Steel Construction (AISC), 1980.

(2) Structural Welding Code (AWS D1.1-84), American Welding Society (AWS), 1984.

(3) Specification for Structural Joints Using ASTM A325 or A490 Bolts, AISC, 1980.

(4) Specification for the Design of Cold-formed Steel Structural Members, American Iron and Steel Institute (AISI), 1980 Edition.

(5) Standard Specifications, Load Tables, and Weight Tables for Steel Joint Girders, the Steel Joist Institute (SJI), 1984.

(6) Criteria for Structural Applications for Steel Cables for Buildings, AISI, 1973 Edition.

(7) Steel Deck Institute Diaphragm Design Manual, Steel Deck Institute, St. Louis, Missouri, 1981.

5.2 CONCRETE

The quality and testing of concrete and steel materials and the design and construction of reinforced concrete components which resist seismic forces shall conform to the following references except as modified by other provisions of this standard:

(1) Building Code Requirements for Reinforced Concrete, (ACI 318-83), American Concrete Institute (ACI), 1983.

(2) Specifications for Structural Concrete for Buildings (ACI 301-84), ACI, 1984.

5.3 WOOD

The quality, design, and construction of members and their fastenings in wood systems which resist seismic forces shall conform to the following references except as modified by other provisions of this standard:

(1) National Design Specification for Wood Construction, 1982, and Design Values for Wood Constrution, 1982, National Forest Products Association, 1982.

(2) American Softwood Lumber Standard, Voluntary Product Standard, PS 20-70, U.S. Department of Commerce, 1970.

(3) Plywood Design Specification, American Plywood Association, 1983.

(4) Construction and Industrial Plywood, Voluntary Product Standard, PS 1-83, U.S. Department of Commerce, 1983.

(5) Standard Specifications for Structural Glued Laminated Timber of Softwood Species, AITC 117-84, American Institute of Timber Construction, 1984.

(6) Structural Glued-Laminated Timber, ANSI/AITC A190.1-1983.

(7) Chapter 25: Wood, in Uniform Building Code, International Conference of Building Officials, 1985.

(8) Part III of the One- and Two-Family Dwelling Code, 1982 editions, published by International Conference of Building Officials, Building Officials and Code Administrators, and Southern Building Code Congress.

(9) Section 4713: "Shear-resisting Construction with Wood Frame," Uniform Building Code, International Conference of Building Officials, 1985.

5.4 MASONRY

The quality and testing of masonry and steel materials and the design and construction of masonry and reinforced masonry components that resist seismic forces shall conform to one or more of the following references, except as modified by other provisions of this standard:

(1) Chapter 24: Masonry, in the Uniform Building Code, International Conference of Buiding Officials, 1985.

(2) Section 4: Reinforced Masonry, in Seismic Design for Buildings, TM 5-809-10, Departments of the Army, Navy and Air Force, 1982.

(3) Building Code Requirements for Concrete Masonry Structures, ACI 531-79, American Concrete Institute, 1979.

(4) American Standard Building Code Requirements for Masonry, A41.1-1953, National Bureau of Standards Miscellaneous Publication, 1954.

(5) Building Code Requirements for Reinforced Masonry, A41.2-1960 (R 1970), American National Standards Institute.

(6) Specification for the Design and Construction of Load Bearing Concrete Masonry, National Concrete Masonry Association, 1970.

(7) Building Code Requirements for Engineered Brick Masonry, Brick Institute of America, 1969.

(8) Part III of the One- and Two-Family Dwelling Code, 1982 edition, published by International Conference of Building Officials, Building Officials and Code Administrators, and Southern Building Code Congress.

5.5 ALUMINUM

The quality, testing, design, and construction of aluminum members which resist seismic forces shall conform to the following reference, except as modified by other provisions of this stardard:

(1) Specifications for Aluminum Structures, 4th Edition, The Aluminum Association, 1982.

5.6 GYPSUM

The quality, testing, design, and construction of gypsum components which resist seismic forces shall conform to the following references, except as modified by other provisions of this standard:

(1) Section 2627: Reinforced Gypsum Concrete, in Uniform Building Code, International Conference of Building Officials, 1985.

(2) Section 4711: Gypsum Wallboard, in Uniform Building Code, International Conference of Building Officials, 1985.

(3) Section 5-05: Gypsum Diaphragms, Cast-in-Place, in Seismic Design for Buildings, TM 5-809-10, Departments of the Army, Navy, and Air Force, 1982.

(4) Standard Specification for Gypsum Concrete, ASTM C317-81, 1981.

(5) Standard Specification for Lightweight Aggregate for Insulating Concrete, ASTM C332-83, 1983.

(6) Recommended Specifications for the Application and Finishing of Gypsum Board, The Gypsum Association, 1982.

(7) Using Gypsum Board for Walls and Ceilings, The Gypsum Association, 1980.

6. STRUCTURAL DESIGN DETAILS

Where a single building includes framing systems that have different values of the coefficient for structural system response, K, each component common to systems having different K values shall satisfy the more stringent detailing requirements.

Portions of the following documents are frequently cited in the provisions of this chapter by a reference number enclosed in square brackets:

[1] Uniform Building Code, International Conference of Building Officials, 1985.

[2] Recommended Lateral Force Requirements and Commentary, Structural Engineers Association of California, 1980.

[3] Seismic Design for Buildings, Departments of the Army, Navy and Air Force (TM 5-809-10), 1982.

[4] Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, American Institute of Steel Construction, 1980.

[5] Building Code Requirements for Reinforced Concrete, American Concrete Institute, 1983 (ACI 318-83).

6.1 MOMENT-RESISTING FRAMES

6.1.1 Ductile Moment-Resisting Space Frames

Ductile moment-resisting space frames shall be structural steel complying with Section 6.2 or reinforced concrete complying with Section 6.3.

6.1.2 Concrete Frames

In Zones 2, 3 and 4, all concrete space frames required by design to be part of the lateral force-resisting system and all concrete frames located in the perimeter line of vertical support shall be ductile moment-resisting space frames.

EXCEPTION:

Frames in the perimeter line of the vertical support of buildings designed with shear walls taking 100 percent of the design lateral forces need only conform with Section 3.2.2.

6.2 STEEL DUCTILE MOMENT-RESISTING SPACE FRAMES

The design and construction of moment-resistant joints for steel ductile moment-resisting space frames shall comply with all applicable requirements for "Type 1 Construction" as defined in reference [4], unless it can be shown that adequate ductility can be obtained by deformations of the connection materials and that the added drift is accounted for.

In addition, steel ductile moment-resisting space frames for all buildings in Zones 3 and 4 and buildings with an Importance Factor I greater than 1.0 in Zone 2 shall comply with the requirements of Section 2722: "Steel Ductile Moment-Resisting Space Frames" of reference [1], or Section 4 "Steel Ductile Moment-Resisting Space Frames" of reference [2], with the following clarification: the requirements for "plastic design sections" are the minimum thickness and lateral bracing requirements (Sections 2.7 and 2.9) of Part II of reference [4].

6.3 REINFORCED CONCRETE DUCTILE MOMENT-RESISTING SPACE FRAMES

The design and construction of concrete ductile moment-resisting space frames for all buildings in Zone 3 or 4 and buildings with an importance factor I greater than 1.0 in Zone 2 shall comply with the requirements of one of the following:

(1) Section 2625: "Reinforced Concrete Structures Resisting Forces Induced by Earthquake Motions" of Reference [1].

(2) Section 2: "Concrete Ductile Moment-Resisting Space Frames" of reference [2].

(3) Paragraph 7-04: "Concrete Ductile Moment-Resisting Space Frames" of reference [3].

Concrete ductile moment-resisting space frames in other buildings shall comply with either the previous requirements or the requirements of reference [5], plus the following requirements of this section. The terms "web reinforcement," "tie," and "spiral" and the symbol "d" in the following shall be used as defined in reference [5].

6.3.1 Flexural Members

Web reinforcement shall be required throughout the length of the member. It shall be designed according to Chapter 11 of reference [5], except that such web reinforcement shall be not less than 0.5 percent of the area computed as the product of the width of the web and the spacing of web reinforcement along the longitudinal axis of the member. The first stirrup shall be located 2 inches from the column face. The next six stirrups shall be spaced not over d/4.

Positive moment reinforcement at all supports of flexural members subject to reversal of moments shall be anchored by bond or mechanical anchors in or through the supporting member to develop the yield strength of the bar.

Lapped splices located in a region of tension or reversing stress shall be confined by at least two closed ties at each splice.

6.3.2 Columns

The spacing of ties at the ends of tied columns shall not exceed 4 inches for a distance equal to the maximum column dimension but not less than one-sixth of the clear height of the column from the face of the joint. The first tie shall be located 2 inches from the face of the Joint. Joints of exterior and corner columns shall be confined by lateral reinforcement through the joint. Such lateral reinforcement shall consist of spirals or ties as required at the ends of columns.

6.4 BRACED FRAMES

In zones 3 and 4 and for buildings having an occupancy importance factor, I, greater than 1.0 located in zone 2, braced frames shall satisfy the following requirements.

6.4.1 Required Capacity

All members in braced frames shall be designed for 1.25 times the force determined in accordance with Chapter 4, STRUCTURAL ANALYSIS PROCEDURES. Connections shall be designed to develop the full capacity of the members or shall be based on the above forces without the one-third increase usually permitted for stresses resulting from earthquake forces.

6.4.2 Steel Braced Frames

Braced frames shall be composed of axially loaded bracing members of ASTM A36, A441, A500, A501, A572 (Grades 42 and 50), or A588 structural steel. A500 steel shall not be welded.

6.4.3 Reinforced Concrete Braced Frames

Reinforced concrete members of braced frames subjected primarily to axial stresses shall have special transverse reinforcing as specified for axially loaded frame members in the requirements cited by reference in Section 6.3 throughout the full length of the member. Tension members additionally shall meet the requirements for compression members.

6.5 REINFORCED CONCRETE SHEAR WALLS

Reinforced concrete shear walls for all buildings in Zones 3 or 4 and buildings with an importance factor I greater than 1.0 in Zone 2 shall comply with the applicable requirements of one of the following:

(1) Section 2625: "Reinforced Concrete Structures Resisting Forces Induced by Earthquake Motions" of reference [1].

(2) Section 3: "Concrete Shear Walls and Braced Frames" of reference [2].

6.6 REINFORCED MASONRY WALLS

Masonry walls required to be reinforced masonry by Sections 6.9 or 7.5 shall comply with the minimum amount and maximum spacing of reinforcement specified in Table 6.1.

Splices may be made only at such points and in such manner that the structural strength of the member will not be reduced. Lapped splices shall provide sufficient lap to transfer the working stress of the reinforcement by bond and shear, but in no case shall the lap be less than 30 bar diameters. Welded or mechanical connections shall develop the strength of the reinforcement.

6.7 DIAPHRAGMS

6.7.1 Ties Between Chords

Diaphragms providing lateral support to concrete or masonry walls by means of anchor bolts or similar connections shall have ties to distribute the anchorage forces into the diaphragm.

6.7.2 Anchorages to Wood Diaphragms

In Zones 2, 3 or 4 where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall not be accomplished by use of toenails or nails subjected to withdrawal; nor shall wood framing be used in cross-grain bending or cross-grain tension.

6.8 OPENINGS IN SHEAR WALLS AND DIAPHRAGMS

Where steps in the edges or openings occur in shear walls or diaphragms or other plate-like elements, chords shall be provided at the edges of the discontinuity to resist the local stresses created by the presence of the discontinuity. These chords shall extend into the body of the wall or diaphragm a distance sufficient to develop and distribute the stress of the chord member.

6.9 CONCRETE AND MASONRY ELEMENTS

6.9.1 Reinforcement

All elements within structures located in Zones 2, 3, or 4 which are of masonry or concrete shall be reinforced so as to qualify as reinforced masonry or concrete under the provisions of Sectiion 6.6 for masonry and reference [5] for concrete.

6.9.2 Anchorage of Walls

Concrete or masonry walls shall be anchored to all floors and roofs which provide lateral support for the wall. Such anchorage shall provide a positive direct connection capable of resisting the horizontal forces specified in this standard or a minimum for of 200 pounds per linear foot of wall, whichever is greater. Walls shall be designed to resist bending between anchors where the anchor spacing exceed 4 feet. Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall.

6.10 FOUNDATIONS

6.10.1 Ties Between Foundation Units

Unless it can be demonstrated that equivalent restraint can be provided by other approved methods, ties at approximately right angles shall be provided between foundation units as follows:

(1) in Zones 2, 3, or 4, between individual pile caps and caissons in all buildings

(2) in Zones 3 or 4, between isolated spread footings in buildings over three stories tall or in buildings constructed over crawl spaces.

The ties shall resist the induced lateral seismic forces, but not less than a minimum horizontal force of 0.10(ZI) times the vertical load on the pile cap, caisson, or footing.

6.10.2 Pile Cap Connections

In Zones 2, 3, or 4, all piles shall be connected to the pile cap to resist an uplift force of not less than 0.15(ZI) times the vertical load on the pile.

6.10.3 Concrete Piles

In Zones 2, 3, or 4, all concrete piles shall be provided with longitudinal reinforcement sufficient to resist the uplift force specified in Section 6.10.2 throughout the entire length of the pile, except that the reinforcement only need be provided in the upper one-third of the pile in Zone 2.

Furthermore, in Zones 2, 3, or 4, all concrete piles shall be provided with transverse ties spaced no further apart than 4 inches over the top 4 feet of the pile.

Properly bonded metal casing, such as steel pipe, may be used to satisfy these reinforcement requirements.

Table 6.1

Minimum Reinforcement and Maximum Spacing for Reinforced Masonry Walls

Type of Wall	Total Area[1] of Reinforcement as a Percent of Gross Area of Wall (nominal dimensions)			Maximum Spacing of Bars[2] (inches)					
				Vertical			Horizontal		
	Seismic Zones			Seismic Zone			Seismic Zone		
	4 & 3	2	1	4&3	2	1	4&3	2	1
Structural (i.e., bearing or shear)	0.20	0.20	0.15	24	36	60	48	60	72
Nonstructural	0.15	0.15	0.15	48	60	72	84	84	96

[1] The total minimum reinforcement is the sum of the vertical and horizontal reinforcement; not less than 1/3 of the prescribed total minimum reinforcement shall be used in each direction.

[2] Principal reinforcement in masonry shall be spaced 2 ft maximum on centers, in buildings using a moment-resisting space frame.

7. NONSTRUCTURAL DESIGN REQUIREMENTS

The requirements of this section apply to all buildings in zones 3 or 4 and to buildings with an importance factor I greater than 1.0 in zone 2.

7.1 ANCHORAGE FOR INERTIAL FORCES

Nonstructural components and their anchorage to the main structural system shall resist the following lateral seismic forces:

$$F_p = ZIC_pW_p \qquad \text{(Eq. 7.1)}$$

where

Z is specified in Section 4.2.1

I is specified in Section 1.4.2 EXCEPT:

1. For connectors of precast or prefabrication panels, the value of I shall be as given in Section 7.2.
2. For the anchorage of machinery and equipment required for life safety systems, the value of I shall be 1.5.

C_p is given in table 7.1.

W_p is the weight of the component, EXCEPT:

1. For storage racks, W_p shall be the weight of the rack plus contents.
2. For ceilings, W_p shall include all light fixtures and other equipment which is laterally supported by the ceiling, and shall be taken as not less than 4 pounds per square foot.

The distribution of these forces shall be according to the gravity loads pertaining thereto.

In lieu of this section, steel storage racks may be designed in accordance with ANSI Standard MH 16.1-1974, or where a number of storage rack units are interconnected so that there are a minimum of four vertical elements in each direction on each column line designed to resist horizontal forces, the racks may be designed as a structure in accordance with 4.2.1 with the design coefficients CS = 0.2 and W equal to the total dead load plus 50 percent of the rack-rated capacity.

7.2 DISTORTION COMPATIBILITY FOR EXTERIOR PANELS

Precast or prefabricated nonbearing, nonshear wall panels or similar elements which are attached to or enclose the exterior shall be designed to resist forces determined from Eq. 7.1 and shall accommodate movements of the structure resulting from lateral forces. The concrete panels or other similar elements shall be supported by means of cast-in-place concrete or mechanical connections and fasteners in accordance with the following provisions:

Connections and panel joints shall allow for a relative movement between stories of not less than the drift calculated in Section 4.4.7 or 1/2 inch, whichever is greater. Connections to permit movement in the plane of the panel for story drift shall be properly designed sliding connections using slotted or oversized holes or may be connections which permit movement by bending of steel or other connections providing equivalent sliding and ductility capacity.

Bodies of connectors shall have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds.

The body of the connector shall be designed for one and one-third times the force determined by Eq. 7.1. Fasteners attaching the connector to the panel or the structure such as bolts, inserts, welds, dowels, etc., shall be designed to ensure ductile behavior of the connector or shall be designed for four times the load determined from Eq. 7.1.

Fasteners embedded in concrete shall be attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

The value of the coefficient I shall be 1.0 for the entire connector assembly in Eq. 7.1.

7.3 PROTECTION AGAINST SECONDARY HAZARDS

Hazardous contents and services shall not present undue hazard to life in the event of seismic ground shaking. As a minimum, for Essential Facilities and High Risk occupancies (I = 1.5 and 1.25, respectively) in zones 3 and 4, the utility and service interface of all gas, high-temperature energy, and electrical supply shall be provided with shutoff devices or special protection.

7.4 FUNCTIONALITY OF ESSENTIAL ELEMENTS

The design and detailing of equipment which must remain in place and be functional following a major earthquake shall be based upon the requirements of Section 7.1. In addition, their design and detailing shall consider effects induced by the structural drift calculated in Section 4.4.7. Special consideration shall also be given to relative movement at separation joints.

7.5 REINFORCEMENT OF CONCRETE AND MASONRY

All nonstructural elements within structures located in zones 3 or 4 which are of masonry or concrete shall be reinforced so as to qualify as reinforced masonry or concrete as defined in chapter 5, DESIGN AND CONSTRUCTION STANDARDS FOR STRUCTURAL MATERIALS and chapter 6, STRUCTURAL DESIGN DETAILS. Principal reinforcement in masonry shall be spaced 2 feet maximum on center in buildings using a moment-resisting space frame.

Table 7.1

Horizontal Force Factors C_p for Nonstructural Elements of Buildings

Component	Direction of Horizontal Forces	Value of of C_p
Exterior and interior walls & partitions Masonry or concrete fences over 6 feet high	Normal to flat surface	0.3
Cantilever elements:		
a. Parapets	Normal to flat surface	0.8
b. Chimneys or stacks	Any direction	0.8
Exterior and interior ornamentations & appendages	Any direction	0.8
When connected to, part of, or housed within a building:		
a. Penthouses, anchorage for chimneys and stacks and tanks, including contents	Any direction	2,3
b. Storage racks with upper storage level at more than 8 feet in height, plus contents		
c. All equipment or machinery		
d. Large ducts, large pipes, and critical or hazardous pipes		
Suspended ceiling framing systems	Any direction	0.3

Table 7.1 (continued)

1. C_p for elements laterally self-supported only at the ground level may be two-thirds of value shown.

2. For flexible and flexibly mounted equipment and machinery, the appropriate values of C_p shall be determined with consideration given to both the dynamic proportion of the equipment and machinery and to the building or structure in which it is placed but shall be not less than the listed values. The design of the equipment and machinery and their anchorage is an integral part of the design and spacification of such equipment and machinery.

3. The value of C_p for racks over two storage support levels in height shall be 0.24 for the levels below the top two levels.

8. CONSTRUCTION QUALITY CONTROL

In accordance with agency quality assurance procedures, all buildings in zones 3 or 4 and buildings with an importance factor I greater than 1.0 zone 2 shall be subject to inspection by the designated authority, and certain types of construction shall have special inspection to assure the quality and performance of the seismic resisting systems, as specified in this section. The requirements in the section supplement existing agency programs, but do not replace them.

8.1 SPECIAL INSPECTOR

A special inspector shall be employed by the designated authority during construction to observe the work specified in 8.2 to be certain it conforms to the design drawings and specifications. The designated authority may waive the requirement for a special inspector if he finds that the construction is of minor nature.

8.1.1 Qualifications

The special inspector shall be a qualified person who shall demonstrate his competence, to the satisfaction of the designated authority, for inspection of the particular type of construction or operation requiring special inspection.

8.1.2 Inspection Reports

The special inspector shall furnish inspection reports to the designated authority, the engineer or architect of record, and other designated persons. All discrepancies shall be brought to the immediate attention of the contractor and the engineer or architect of record for correction, then, if uncorrected, to the designated authority.

8.1.3 Final Report

The special inspector shall submit a final signed report stating whether the work requiring special inspection was, to the best of his knowledge, in conformance with the approved plans and specifications and the applicable workmanship provisions of these codes.

8.2 REQUIRED SPECIAL INSPECTION

The following objects and operations shall be subject to continuous inspection by a special inspector. Some inspections may be made on a periodic basis and satisfy the requiremunts of continuous inspection, provided this periodic scheduled inspection is performed as outlined in the project plans and specifications and approved by the designated authority. Special inspections required by this standard shall not be required where the work is done on the premises of a fabricator approved by the designated authority to perform such work without special inspection.

8.2.1 Piling, Drilled Piers and Caissons

During driving and testing of piles and construction of cast-in-place drilled piles or caissons. See Sections 8.2.3 and 8.2.4 for concrete and reinforcing steel inspection.

8.2.2 Excavation and Filling

During earthwork excavations, grading, and filling operations inspection to satisfy the requirements of the plans and specifications.

8.2.3 Concrete

During the taking of test specimens and placing of all reinforced concrete and pneumatically placed concrete.

EXCEPTIONS:

(1) For foundation concrete when the structural design is based on f_c no greater than 2000 psi.

(2) Nonstructural slabs on grade, including prestressed slabs on grade when effective prestress in concrete is less than 150 pounds per square inch, unless the slab is used as a tie to satisfy Section 6.10.1.

(3) Site work concrete full-supported on earth and concrete where no special hazard exists.

8.2.4 Reinforcing Steel and Prestressing Steel

During all stressing and grouting of prestressed concrete, and during placing of reinforcing steel, placing of tendons and prestressing steel for all concrete required to have special inspection by Section 8.2.3.

EXCEPTION:

The special inspector need not be present during entire reinforcing steel and prestressing steel-placing operations, provided he has inspected for conformance with the approved plans prior to the closing of forms or the delivery of concrete to the job site.

8.2.5 Ductile Moment-Resisting Concrete Frame

Continuous inspection by a specially qualified inspector under the supervision of the person responsible for the structural design during the placement of reinforcement and concrete.

8.2.6 Welding

(1) All structural welding, including welding of reinforcing steel.

EXCEPTIONS:

When welding is done in an approved fabricator's shop; or when approved by the designated authority, single-pass fillet welds when stressed to less than 50 percent of the allowable stresses and floor and roof deck welding and welded studs when used for structural diaphragm or composite systems may have periodic inspections. For periodic inspection, the inspector shall check qualifications of welders at start of work and then make final inspection of all welds for compliance prior to completion of welding.

(2) Ductile moment-resisting steel frames shall receive the following nondestructive testing:

Welded connections between the primary members of ductile moment-resisting space frames shall be tested by nondestructive methods, either ultrasonic testing or radiography, for compliance with the AWS Structural Welding Code (D1.1-84) and job specifications. A program for this testing shall be established by the engineer responsible for structural design and as shown on plans and specifications. As a minimum, this program shall include the following:

(a) All complete penetration groove welds contained in joints and splices shall be tested, 100% either by ultrasonic testing or radiography.

EXCEPTION:

When approved, the non-destructive testing rate for an individual welder or welding operator may be reduced to 25 percent, provided the reject rate is demonstrated to be five percent or less of the welds tested for the welder or welding operator. A sampling of at least 40 completed welds for a job shall be made for such reduction evaluation. Reject rate is defined as the sample number of welds that do not pass the tests divided by the sample number of welds inspected. For evaluating the reject rate of continuous welds over 3 feet in length where the effective size is 1 inch or less, each 12-inch increment or fraction thereof shall be considered as one weld. For evaluating the reject rate on continuous welds over 3 feet in length where the effective size is greater than 1 inch, each 6 inches of length or fraction thereof shall be considered one weld.

When approved by the designated authority and outlined in the project plans and specifications, this nondestructive testing may be performed in the shop of an approved fabricator utilizing qualified test techniques in the employment of the fabricator.

(b) All partial penetration groove welds when used in column splices shall be tested when required by the plans and specifications.

(c) Base metal thicker than 1-1/2 inches, when subjected to through-thickness weld shrinkage strains, shall be inspected by ultrasonic testing or radiography for discontinuities directly behind such welds after joint completion. Any material discontinuities shall be accepted or rejected on the basis of the defect rating in accordance with the criteria of the AWS Structural Welding Code (DI.1-84).

8.2.7 High-Strength Bolting

During all bolt installations and tightening operations.

EXCEPTIONS:

(1) The special inspector need not be present during the entire installation and tightening operation, provided he:

(a) inspects the surfaces and bolt type, including diameter and length, for conformance to plans and specifications prior to start of bolting, and

(b) will verify the minimum specified bolt tension for 10 percent of the bolts for each "type" of connection, for a representative number of total connections established by the plans and specifications.

(2) In bearing-type connections when threads are not required by design to be excluded from the shear plane, inspection prior to or during installation will not be required.

8.2.8 Structural Masonry

During preparation of masonry wall prisms, sampling and placing of all masonry units, placement of reinforcement, inspection of grout space, immediately prior to closing of cleanouts, and during all grouting operations. Where the f is less than 2600 psi and special inspection stresses are used, test specimens may consist of either one prism test for each 5000 square feet of wall area or a series of tests based on both grout and mortar for the first 3 consecutive days and each third day thereafter. EXCEPTION: Special inspection will not be required for structures designed in accordance with the values in appropriate tables for noncontinuous inspection.

8.2.9 Reinforced Gypsum Concrete Used as a Diaphragm

When cast-in-place Class "B" (1000 psi minimum compressive strength) gypsum concrete is being mixed and placed.

8.2.10 Insulating Concrete Used as a Diaphragm

During the application of insulating concrete.

EXCEPTION:

The special inspection may be limited to an initial inspection to check the deck surface and placement of reinforcing. The special inspector shall supervise the preparation of compression test specimens during this initial inspection.

8.2.11 Special Cases

Any other work which, in the opinion of the designated authority requires special inspection.

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SEISMIC DESIGN GUIDELINES FOR FEDERAL BUILDINGS

- COMMENTARY -

C1. REGULATION

C1.1 SCOPE

These guidelines are primarily intended for new buildings. Structures that are not associated with buildings are outside the scope because their particular functional requirements and the nature of hazard they present have not been considered in developing the requirements of these guidelines and because the idealization of seismic loadings presented in these guidelines may not be an appropriate model for predicting their physical response to seismic ground shaking. Another exception is that buildings and structures associated with nuclear power plants are subjected to the more rigorous requirements of the Nuclear Regulatory Commission.

The coverage of existing buildings in these guidelines is brief; future reports planned for issue by the Interagency Committee on Seismic Safety in Construction (ICSSC) are expected to provide more specific criteria for those occasions when the requirements of these guidelines indicate the need for their application. The application of these guidelines to Federally leased buildings and to Federal grant and regulatory programs is also expected to be covered in future ICSSC reports.

The reference to varying degrees of safety is, in part, a recognition that different levels of reliability are desired for buildings that present different risks. Just as in the Uniform Building Code (UBC), these guidelines accomplish this purpose by means of a numerical coefficient (the Importance Factor, I) for occupancy hazard, which is specified in Section 1.4.2. The statement is also a recognition that some provisions are based on approximations and may result in different levels of safety for different situations.

These guidelines are limited to consideration of the effects of seismic ground shaking. Other seismic effects, such as tsunami, and other environmental loads, such as wind, are not within the scope. Existing codes and standards commonly contain clauses pertaining to wind forces in many provisions, such as stiffness and overturning resistance. No such clause is in these guidelines, because criteria for resistance to the two forces are too different. The response to seismic ground shaking will ordinarily require inelastic straining of the seismic force-resisting system, thus the many ductility and detailing requirements in these guidelines must be satisfied even for buildings in which wind force exceeds the nominal design seismic force. For buildings in which the nominal design seismic force exceeds the nominal design wind force, it is likely that wind requirements may yet control the design of various components because the local pressure and suction coefficients may create higher force resultants or because the drift criterion is different for wind than for seismic loadings, and so on. Thus, no comparisons of the two loadings are stated or implied in the provisions of the guidelines. Similarly, design for seismic does not exclude the need to evaluate other non-seismic sources of loading such as wind.

C1.2 DEFINITIONS

The bulk of the definitions are taken from, or based upon the Uniform Building Code. In all the definitions an emphasis has been placed on lateral seismic forces when compared to the definitions in the UBC, although are sources are used. The reference is shown below for each definition. Unless otherwise noted, the source definition is used word for word.

approved - UBC Section 402 (except the term "designated authority," which is defined in these guidelines, is substituted for the term "building official")

base of structure - UBC Section 2312(b)

bearing wall - UBC Section 424

box system - Modified from UBC 2312(b) which reads "Box system is a structural system without a complete vertical load-carrying space frame. In this system the required lateral forces are resisted by shear walls or braced frames as hereinafter defined." The change was thought to be simpler and clearer but was not intended to change the meaning. Also see the discussion in Chapter 3 of this commentary.

braced frame - UBC Section 2312(b), except "lateral forces" is changed to "lateral seismic forces" and "by the seismic forces" is added after axial stresses. The rewording was done to clarify that the source of the lateral forces is due to an earthquake and not some other source such as wind.

building - UBC Section 403

dead load - UBC Section 2302

designated authority - The definition is original, and in the context of the UBC it can be thought to replace the term building official (which uses similar wording in its definition) which was not appropriate for use in these guidelines since the government representative may not be a building official.

diaphragm - A definition was not available in the UBC. The definition is based upon that used in Chapter 2 of the NEHRP Provisions and is similar to ANSI A58.1.

dual system - Not explicitly defined in the UBC. The definition can be inferred from UBC Table 23-I from the description of a system using a K factor of 0.80. Since the phrase is widely used, a formal definition was desirable. Also see discussion in Chapter 3 of this commentary.

ductile moment-resisting space frame - Based on UBC Section 2312(b) which uses "Ductile moment-resisting space frame is a moment-resisting space frame complying with the requirements for a ductile moment-resisting space frame as given in Section 2312(j)." The requirements given in that section are intended to provide the capability to undergo inelastic straining. Similar requirements are in these guidelines.

ductile moment-resisting space frame system - A similiar phrase is not used in the UBC but is used in the NEHRP Provisions. Its use simplifies discussion of seismic resisting resisting systems. Also see discussion in the Chapter 3 of this commentary.

essential facilities - UBC Section 2312(k)

exterior wall - UBC Section 424

height - The definition is original, but is consistent with the use of the terms in the UBC. UBC uses the phrase "height of building" defined in Section 409.

high risk facility - The phrase is not explicitly used in the UBC; however, the phrase was developed for use with the UBC description of the building used for the type of occupancey requiring an importance factor of 1.25 in

UBC Table 23-K. The definition used here and the description in the UBC are identical.

live load - UBC Section 2302

moment-resisting space frame - Based on UBC Section 2312(b) which reads " Moment-resisting space frame is a vertical load-carrying space frame in which trhe members and joints are capable of resisting forces primarily by flexure." The phrases are added for clarity and emphasis and are not intended to change the definition.

parapet wall - UBC Section 424

seismic force-resisting system - The phrase is not used explicitly in the UBC. The definition is based on a modification of that used in Chapter 2 of the NEHRP Provisions.

shear wall - UBC Section 2312(b)

space frame - UBC Section 2312(b). The definitions which are repeated here are for the purpose of clarifying the various types of space frames.

structure - UBC Section 420

C1.3 NOTATION

Each of the symbols used in section 2312(c) of the UBC is used for the same meaning in these guidelines. The verbal expression defining a few of the symbols is changed from the UBC in an attempt to make the collected notation more complete; however, the use in the various equations has not changed. Additionly, the section and equation in which the symbol is used is frequently provided in the definition. In addition, several new symbols are added for modal analysis equations that appear in these guidelines that are not found in the UBC since the UBC does does not cover dynamic analysis. Only modified or new symbols are discussed below.

Modified Symbols

C - Adds the phrase "for the vibratory response of a structure to to seismic motions" to clarify use of the symbol.

C_p - Adds the phrase "for the vibratory response of a part of a structure to seismic motions" to clarify use of the symbol.

F_i, F_n, F_x - Changes the phrase "lateral force" to "lateral seismic force" to clarify the source of the loading.

F_p - Changes the phrase "lateral" to "lateral seismic force to clarify the source of the loading.

I - Adds the phrase "numerical coefficient for occupancy hazard" to clarify the use of the symbol.

K - Adds the phrase "numerical coeffieient for structural system response to seismic motions" to clarify the use of the symbol.

S - Adds the phrase "in response to seismic motions" to clarify the use of the symbol.
V - Changes the phrase "lateral force" to "lateral seismic force" to clarify the source of the loading.

Z - Adds the phrase "for the seismic hazard zone" to clarify the use of the symbol.

$_i$ - Adds the phrase "used in determing the period of vibration" to clarify the use of the symbol.

New symbols for use with modal analysis

$\bar{C}$, C_m, F_{xm}, M_{xm}, $\bar{T}$, T_m, $\bar{V}$, V_m, V_t, V_{xm}, W_m, ϕ_{im}, ϕ_{xm}

C1.4 HAZARD CLASSIFICATIONS

Buildings are classified on two scales in these guidelines, much as they are in the UBC. One scale, the zone, related to the likelihood of seismic activity, and the other scale, the occupance importance factor, relates to the consequences of structural failure due to an earthquake. These classifications are used throughout the guidelines to determine the applicability of specific requirements. Table C1 summarizes, very generally, the use of these hazard classifications for this purpose. It should be noted that there are several differences with the UBC.

C1.4.1 Seismic Ground Shaking Hazard

The map in this document has been derived from the "Effective Peak Velocity-Related Acceleration" map contained in the NEHRP Commentary. It has the following characteristics necessary for consistent use with the basic provisions of the guidelines:

(1) It is a zone map, not a contour map, with Zones, 0, 1, 2, 3, and 4.

(2) The boundaries are smooth lines that do not necessarily accomplish microzonation.

(3) The relative design acceleration for the five zones 4 through 0 is in the proportion 1 : 3/4 : 3/8 : 3/16 : 0, respectively.

There are other maps with these characteristics. The Subcommittee on Standards for Buildings preferred this particular map over the current UBC map because it was developed on a basis of consistent risk across all zones and over the NEHRP "Effective Peak Acceleration" map because it accounts for the effect of large, distant earthquake on tall buildings. The map is the same as that used in ANSI A58.1 and similar to the one proposed by SEAOC for a UBC Code change.

It is expected that improvements will be made in the map as knowledge is accumulated in the extensive research programs ongoing in seismic hazard assessment. It should be expected that individual site evaluations will vary with regard to this map, because it is not possible to microzone with such a microzone with such a map. These variations may be particularly significant in the zones of highest seismicity. Various catalogs are available that correlate the seismic hazards in cities of interest around the world with the seismic hazard zones used for design in the United States.

Some buildings will be located on sites for which a comprehensive site evaluation will have been performed, and thus a site-specific value for design ground acceleration will occasionally be available. It is not possible to microzone on the map included in these guidelines and thus, in many instances, such site specific accelerations may not be equivalent to the ground acceleration implied by the map. The relation to obtain a zone from a value of site-specific ground acceleration is provided for such buildings. Such a relation is necessary for the proper application of detailing requirements that depend on the zone even though the seismic forces on such buildings will normally be calculated directly from the site-specific ground acceleration. The relation for the conversion is based on the assumption that the design ground motion would have, roughly, a 0.002 chance of being exceeded in one year. For approved site evaluations based on a different probability of earthquake occurence, the values in the table should be adjusted accordingly. The assumption corresponds to the basis for the map in this document.

C1.4.2 Occupancy Hazard

The categories of occupancies in this section are the same as in section 2312(k) and Table 23-K of the UBC with these exceptions: power stations and other emergency utilities are added to the essential category, and buildings in which the occupant's mobility is restricted or impaired or in which the contents are hazardous are added to the high risk category. The term "high risk facility" is new in this document but its definition (see definition commentary) is the same as the description of the use in UBC.

Occupancy Importance can be a relative matter. For example, small police stations might be of less concern than a headquarters building. Similarly, all hospitals may not be of equal importance. The single hospital that provides the only service in a large isolated area is a critical resource. But a hospital that is one of many may, if necessary, transfer its services to others. In some instances, a small nursing home may become critical. General guidance on these matters is outside the scope of these guidelines. Local emergency plans may be the most appropriate means of attackinlg such matters.

C1.5 ALTERNATIVE PROVISIONS

This provision is very general and is intended to allow new and/or innovative systems and means of analysis not covered in the guidelines to be used if they satisfy the designated authority as to their level of safety. Similar provisions are found in Section 2312(a) of UBC for materials and Section 2312(i) of UBC for analytical methods.

TABLE C1 - APPLICABILITY OF REQUIREMENTS

Zone	Occupancy Importance Factor		
	1	1.25	1.5
0	(a)	(a)	(a)
1	(b)	(b)	(b)
2	(b)	(c)	(c)
3	(c)	(c)	(c)+(d)
4	(e)	(e)	(e)+(d)

KEY:

(a) no requirements apply

(b) basic structural resistance required

(c) provisions consistent with current practice in California required, including upgraded ductility, nonstructural component resistance, and improved quality control

(d) special site evaluations required for some buildings

(e) modal analysis required for some buildings

C2. GENERAL REQUIREMENTS

This document is intended to be self contained with regard to seismic design requirements. Thus this chapter contains general provisions that might apply to all areas of design and not just seismic. Accordingly they would be found in the general requirements of a building code and not specifically in a chapter on seismic design.

C2.1 GENERAL PERFORMANCE REQUIREMENT

This very general requirement is essentially the same as the first sentence of the seismic provisions in UBC Section 2312(a). The exemption for Zone 0 merely gives formal recognition to present practice, although designers would be well advised to satisfy the intent of Section 3.1.1 of these guidelines even in Zone 0, particularly for important structures.

C2.2 SITE PLANNING FOR NEW BUILDINGS

C2.2.1 Site Evaluation Study

This section is quite similar to the present practice of the Army, Navy, Air Force, and the Veterans Administration. The requirement is not arbitrarily applied to all essential facilities in high risk zones for reason of economics. The cost of the site evaluation could exceed the cost of the building for very small important structures such as some fire stations, which might not be the most efficient way of providing the additional reliability desired. Nor should the requirement for all hospitals be arbitrarily extended to all medical buildings; clinics and other small medical facilities may be provided with additional safety without resorting to full site evaluations. Thus, the designated authority is called upon to judge each case on its own merits. Procedures for carrying out site evaluation studies and guidelines for the approval of site evaluation studies are described in TR-2, "Evaluation of Potential Surface Faulting and other Tectonic Deformation;" TR-3, "Evaluation of Earthquake-Induced Ground Failure;" TR-6, "An Introduction to Technical Issues in the Evaluation of Seismic Hazards for Earthquake-resistant Design;" and TR-8, "Tsunamis: Hazard Definition and Effects on Facilities" all published by the Interagency Committee on Seismic Safety in Construction.

C2.2.2 Site Limitations

Note that the requirement for siting essential facilities to avoid surface rupture due to fault displacement does not apply to those essential facilities for which no site evaluation study is performed. Various engineering solutions for liquefaction, landslide, and subsidence problems exist, but no criteria are provided in these guidelines. The ICSSC manuals previously referenced include some information on these subjects.

C2.3 DESIGN OF NEW BUILDINGS

The bulk of these guidelines deals with design. This section merely establishes the applicability of the design requirements and requires a standard amount of documentation to confirm compliance with the requirements.

C2.4 CONSTRUCTION

The importance of quality assurance cannot be overstated. Federal agencies have general quality assurance programs; this provision supplements, but does not replace, those agency provisions in the higher seismic zones for issues of special concern in seismic safety.

C2.5 EXISTING BUILDINGS

C2.5.1 Alterations and Repairs

These guidelines contain limited criteria for existing buildings. Future reports by the ICSSC will include more detail on the subject. The UBC requirement in Section 104(b) for existing buildings is rather different and is quoted below:

> Additions, alterations or repairs may be made to any building or structure without requiring the existing building or structure to comply with all the requirements of this code, provided the addition, alteration or repair conforms to that required for a new building or structure. Additions or alterations shall not be made to an existing building or structure which will cause the existing building or structure to be in violation of any of the provisions of this code nor shall such additions or alterations cause the existing building or structure to become unsafe. An unsafe condition shall be deemed to have been created if an addition or alteration will cause the existing building or structure to become structurally unsafe or overloaded; will not provide adequate egress in compliance with the provionons of this code or will

> obstruct existing exits; will create a fire hazard; will reduce required fire resistance or will otherwise create conditions dangerous to human life. Any building so altered, which involves a change in use or occupancy, shall not exceed the heighty, number of stories and area permitted for new buildings. Any building plus new additions shall not exceed the height, number of stories and area specified for new buildings. Additions or alterations shall not be made to an existing building or structure when such existing building or structure is not in full compliance with the provioions of this code except when such addition or alteration will result in the existing building or structure being no more hazardous based on life safety, fire safety and sanitation, than before such additions or alterations are undertaken.

The second paragraph of 2.5.1 is taken from 2312(j)2A of the UBC. Note that overstrengthening one portion of a building could cause higher loads in other portions of the building and thus should be avoided.

C2.5.2 Changes of Use or Location

This section is similar to intent and wording of UBC Section 104(e) which says "Buildings or structures moved into or within the jurisdiction shall comply with the provisions of this code for new buildings or structures" except that change of use is added to the requirement.

C3. STRUCTURAL DESIGN CRITERIA

Chapter 3 includes the governing criteria for the structural portions of a building. Reference is made to Chapter 4 for the determination of the force effects of seismic ground shaking, to Chapter 5 for the basic standards for proportioning structural components, and to Chapter 6 for special details important to assure the assumed behavior of the seismic force-resisting system in an earthquake.

C3.1 SEISMIC FORCE-RESISTING SYSTEMS

The ground motions observed in past large earthquakes are greater than those corresponding to the forces prescribed in this document (or in any other current standards for ordinary structures). In spite of discrepancy between real and implied ground motions, many buildings designed according to the UBC and similar standards have performed well in past earthquakes. The seismic force-resisting systems described in some detail in this section are based on UBC Section 2312(j) and UBC Table 23-I. There is no intended conflict between these guidelines and the UBC. However, it is intended that the organization of the material will clarify the systems and selection of K-factors.

There are several factors that contribute to this successful performance, but ductility, the ability of a structure to be strained beyond its elastic limit, is probably the most important factor. Large earthquakes will ordinarily subject some portions of a building to repeated cycles of inelastic strain. Thus, it is important for a designer to define a seismic force-resisting system. The seismic force-resisting system must be designed and constructed with special attention so that it will maintain its resistance while undergoing the repeated cycles of inelastic straining caused by strong ground shaking.

The seismic force-resisting system will frequently be a subset of the overall structural system. For example, in a building with many frame bents in each direction, a few in each direction might be designated as seismic force-resisting and designed as ductile moment-resisting space frames or as braced frames. Although it would not be a common occurrence, it is possible for a designer to use a two-level approach in this. In such an approach, components more rigid yet less ductile than the designated seismic force-resisting system are considered effective in moderate earthquakes. Such components may not be used to satisfy the strength criteria of 3.1.3, but may be used to satisfy the stiffness criteria of 3.1.4.

C3.1.1 Integrity

This requirement, taken from the NEHRP provisions, is very elementary, so much so that its consideration is recommended even in Zone 0 where seismic design consideration is not required.

Movement of the ground beneath a building generates inertial forces due to each mass within the building, because the building responds as an integral unit in the motion. This provision simulates the effect of these inertial forces by specifying equivalent seismic forces to be applied at each story. This requirement reminds the designer that the simulation is complete only when the specified seismic forces are carried back into the ground, which is the "final point of resistance." Conspicuous failures of building components in past earthquakes can be attributed to the lack of a complete and continuous path of structural resistance for seismic loads.

C3.1.2 System Response Classification

Seismic force-resisting systems possess different degrees of ductility, damping, redundancy, etc. These important characteristics affect the level of inertial force generated by a given ground motion and level of safety for a given level of force. Therefore, different seismic force coefficients and detailing rules are specified for various types of seismic force-resisting systems. The four classes defined in this section are taken from the UBC. The exact description of the systems is slightly different than in the UBC, but the changes are only an attempt to clarify the classification. The SEAOC Commentary provided the basis for discerning the intent of the original classification.

Several features of the classification deserve comment. The first decision in classifying a building concerns bearing walls. This decision often requires experienced judgment. Buildings in which "a significant fraction of the gravity load is supported on bearing walls" must be classed as a "Box System" in each principal direction. The presence of minor load bearing walls (for example, around a stairwell within one bay of the frame) does not mean that a building must be categorized as a "Box System" if the overall response of the building is not significantly influenced by the walls. The seismic force-resisting system of "Box Systems," will normally include the bearing walls functioning as shear walls plus any other designated components. Buildings that are not classed as "Box Systems" may be classed separately about their two principal axes.

The second important decision regards the use of ductile moment-resisting space frames in the designated seismic force-resisting system. Because rigid elements may exist in buildings without being a part of the designated seismic force-resisting system, it is possible for a building with both ductile moment-resisting space frames and shear walls (or braced frames) to be in any of the three remaining classes, as follows:

1) where the designated seismic force-resisting system includes only the ductile moment-resisting space frame, K = 0.67 is correct;

2) where the designated seismic force-resisting system includes both types of components and where the relative strengths of the two types of components satisfy the requirements of Section 3.1.3, K = 0.80 is correct:

3) otherwise, K = 1.00 is correct.

The classification of such buildings becomes quite complex when the two level approach mentioned in the commentary on seismic force-resisting systems is adopted.

A great variety of seismic force-resisting systems is included in the "Building Frame System" class, such as shear walls, braced frames, arches, moment-resisting frames that do not meet the special ductility requirements of chapter 6, etc.

Section 3.1.6 places restrictions on the class of seismic-force resisting systems allowed for tall buildings in zones 2, 3, and 4. This is also done in UBC Section 2312(j).

C3.1.3 Strength

This provision is consistent with the UBC, Table 23-I is the source. The intent is to continue present UBC practice unchanged, which generally means increasing the allowable stress by 1/3 when considering the effects of seismic forces. Increases in allowable stresses and factors for the combinations of loads are specified in the material design standards referenced in Chapter 5.

C3.1.4 Stiffness and Building Separations

Although the number looks quite different, these requirements are essentially the same as Section 2312(h) of the UBC. Drift limits are imposed on the basis of experience and judgment. The principal reasons are to ensure that the stiffness is large enough to prevent stability failures and to control life hazards resulting from the failure of brittle nonstructural elements such as windows. In both cases the protection provided by the specified drift limit is only approximate. An added, but not primary, reason for the drift limit is to reduce damage and repair costs following moderate earthquakes. The designer should recognize that the actual deflections and drifts will be larger than those calculated on an elastic basis, due to the inelastic straining of the seismic force-resisting system. The SEAOC Commentary states that the real deflections will exceed the calculated elastic deflections by a factor of 3/K. Thus, the UBC limit of 0.005 times the story height is simply a nominal value applied to the elastic deflections. The SEAOC Commentary further advises that the anticipated real deflections rather than the elastic deflections be used in determining the distance necessary for structural separation joints. In order to avoid confusion and reduce the number of computations, all deflections and drifts are multiplied by 3.0/K, but with 3.0/K not less than 3.0 (in 4.4.7) and the drift limit in Section 3.1.4 is correspondingly changed by a factor of 3.0 from 0.005 to 0.015.

C3.1.5 Overturning Stability

This requirement is the same as that in section 2312(f) of the UBC, except that wind is not mentioned, for the reasons stated in C1.1. Overturning stability has rarely been a problem in real buildings subject to earthquakes. The calculated overturning moment is likely to be conservative because these provisions do not account for the rocking of a building on its foundation, the lengthening of the period of vibration due to inelastic effects below the base and in the soil, the contributions of the higher modes of vibration (except in Section 4.4.4 for tall buildings), and other similar factors which tend to reduce the real overturning in the building. Therefore, no margin of safety is called for between the overturning and resisting moments.

C3.1.6 Height

The requirement is essentially the same as Section 2312(j)1B of the UBC. Its impact is that buildings over 160 feet high in the specified zones will have structural systems that qualify for a K value of 0.67 or 0.80.

C3.2 OTHER STRUCTURAL ELEMENTS

Seismic ground shaking affects the entire structural system, not just the designated seismic force-resisting system. These effects are primarily of two types, the inertial forces due to the mass of the structural element and the distortions the structural element experiences as the seismic force-resisting systems responds to the ground shaking.

C3.2 Other Structural Elements

C3.2.1 Strength and Anchorage

This requirement is based on Section 2312(g) of the UBC. It applies in Zone 1, just as the basic requirements for the seismic force-resisting system in Section 3.1. The increase in allowable stresses by 1/3 normally permitted in reference standards for seismic forces is applicable when satisfying this requirement.

C3.2.2 Compatibility

This requirement is taken from Section 2312(j)1D of the UBC. The distortion specified in Section 4.4.7 (which includes the amplification by the factor 3/K) is intended to include both the ductility of the seismic force-resisting system and the P-delta effect, as indicated in the SEOAC Commentary.

C3.3 FOUNDATIONS

C3.3.1 Soil and Foundation Capacity

This requirement is very performance oriented, by necessity. It is not possible to develop specific provisions at this time because soil and foundation conditions for buildings exhibit such a wide variety. The wording used is quite similar to the NEHRP provisions. The intent is to cause the geotechnical engineer and the foundation engineer to be cognizant of the differing effects of ground shaking on the properties of various soil types when establishing the allowable bearing pressures and other design criteria for load combinations involving earthquake. The performance objectives are to avoid bearing capacity failures and to avoid settlements so severe as to cause failure of the structural system of the building. The requirement should not be interpreted to imply that soil-structure interaction analyses are necessary; such analyses may be useful for special types of structures with specific soil and foundation conditions, but that is an issue to be decided on a case by case basis.

C3.3.2 Structural Ductility

As this provision indirectly indicates, the base and the foundation of a structure need not be the same entity. For a building with one or more levels below grade in which the levels below grade are considerably more stiff than the levels above grade and the soil around the basement levels is not exceptionally soft, the base can be considered to be at grade, because the most accurate simple model is to consider that the rigid substructure moves with the surrounding ground in imparting the motions to the superstructure. On the other hand, buildings in which the soil around the basement levels is exceptionally soft are more accurately modeled by considering the base to be at the foundation level. For those buildings in which the base is above the foundation, it is only reasonable that the ductility of the seismic force-resisting system be continued to the foundation.

C4. STRUCTURAL ANALYSIS PROCEDURES

This chapter provides for the calculation of seismic loads and their effects. The SEAOC Commentary is a valuable resource for better understanding of the provisions in this chapter. The reader is referred to that resource.

C4.1 REQUIRED METHOD FOR SEISMIC-RESISTING SYSTEMS

The minimum level of analysis, contained in Section 4.2, is the same as UBC except as noted and is thought appropriate for most buildings. The modal analysis, contained in Section 4.3, is somewhat similar to the NEHRP provisions and is appropriate for multistory buildings that are not uniform throughout their height. This provision of analytical procedures for irregular buildings should not be inferred to encourage such buildings. Indeed, because such buildings have been shown to be more vulnerable in past earthquakes and because their response is considerably more difficult to predict, irregular buildings are discouraged.

It should be noted that soil-structure interaction analyses will generally have the effect of reducing the forces and increasing the deflections in the structure. In some instances, secondary geometrical effects resulting from the increased deflections will have the effect of a net increase on the forces.

C4.2 ELASTIC STATIC LOAD ANALYSIS

Section 4.2 is based on Sections 2312(d) and (e) of the UBC. Unless otherwise noted herein or elsewhere in this document, the same equations, meanings, and limits are used in both these guidelines and the UBC.

C4.2.1 Base Shear

This section combines Sections 2312 (d) and (e) of the UBC. An additional provision for determining Z is provided for those buildings on sites with an approved site evaluation. This is simply a means of calibrating the spectrum for base shear to the site acceleration. If the site acceleration is greater than 40 percent of gravity, the resulting Z will be greater than 1.0. This Z value is required for determining ductility requirements. Permanent loads that are fixed to the structure, such as some types of computer installations, should be included in W. When dealing with liquids, W should be the weight of the effective mass.

C4.2.2 Period of Vibration

The equations for calculating the period are the same as given in the UBC Section 2312 (d). Equations 4.3 and 4.4 are approximate and are based on the periods found in actual buildings. The use of a proper analysis for the period is encouraged, but a limit is placed on the result in order to prevent the use of periods significantly larger than observed in real buildings. Use of unrealistically large values for the period results in low and unsafe values for the base shear. UBC does not contain such limits. The limit used in these guidelines is the same as that used in ANSI A58.1 which uses the same set of formulas for determining the period.

C4.2.3 Site Coefficient

Two alternative methods are presented. Both methods are specified in the 1985 UBC Section 2312(e). Method A has been used for several years in the highly seismic areas of the country. It requires the determination of a value for the site period, for which SEAOC Standard No. 1, "Determination of the Characteristic Site Period, Ts" is recommended (also published as UBC Standard No. 23-1).

Method B was incorporated in UBC in 1985 after appearing in an earlier draft of these guidelines. In this method, Soil Profile Type 3 is specified for sites at which the soil properties are not known in detail. This may be conservative since the designer would possibly be aware of the soil properties at sites actually fitting Soil Profile Type 3 because of the likely need for deep or special foundations. The NEHRP Provisions specifies Soil Profile Type 2 for this case while ANSI A58.1 specifies that the soil profile resulting the larger value of the product CS be used.

C4.2.4 Vertical Distribution of Forces

The provision for irregular shapes or frames is based on the combination of UBC Sections 2312(e)2 and 3. The provision for regular shapes and framing systems is based on UBC Section 2312(e)1. The provisions are the same.

The specified distribution is based on buildings in which the stiffness, mass, and strength are relatively consistent from one level to the next. The proceduress of 4.3 will account for the lack of such consistency in stiffness and mass, but more sophisticated analyses are required for substantial differences in strength.

C4.3 ELASTIC DYNAMIC LOAD ANALYSIS

This analysis is only applicable to multistory buildings. The UBC has no provisions for dynamic analysis. Accordingly, the provisions are based on the NEHRP procedures for modal analysis, although they are not as detailed. The intent is to establish the basic limits for such analyses rather than to completely specify a method. The design spectrum is not from the NEHRP, but is simply consistent with the spectrum used in Section 4.2.1. Although the combination of modes by means of the common square root of the sum of the squares method is specified, more precise combinations may be necessary for buildings with closely coupled modes.

C4.3.3 Design Values

The limits placed on the base shear are intended to prevent misuse of advanced analyses. The reason to use the advanced analysis is primarily to determine the distribution of seismic forces more accurately, not to reduce the overall force. The 90 percent limit is an arbitrary limit which is also used in ANSI A58.1

C4.4 ELASTIC LOAD EFFECT ANALYSIS

Except where noted, the provisions of 4.4 are taken from Sections 2312 (e) and (f) of the UBC.

C4.4.1 Shear

It is frequently useful to idealize the relative rigidity of horizontal to vertical bracing systems as "flexible" or "rigid." For "flexible" diaphragms (or bracing systems), the shear is distributed from the diaphragm to the vertical elements by modeling it as a beam on unyielding supports. The amount of shear in a particular wall or frame would depend on the shear in the diaphragm spans that are tributary to it. There would be no effect of continuity in the diaphragm, since the shear strain normally dominates the flexural strain in the diaphragm. For the "rigid" diaphragm, the shear is distributed by modeling the diaphragm as a rigid beam on yielding supports. The amount of shear in a particular wall would depend on its rigidity in relation to all other walls. Buildings with plywood deck diaphragms and masonry or concrete shear walls are normally considered to have "flexible" diaphragms, while buildings with concrete slabs of normal proportions without large openings are normally considered to have "rigid" diaphragms. Where the horizontal and vertical bracing systems have equivalent rigidities, a more complex analysis is required. For such cases, it is normally acceptable to conduct two simple analyses, one for each of the previously described extremes, and use the more conservative values for design.

C4.4.2 Horizontal Torsion

In consideration of the commentary on 4.4.1, the phrase, "Where the vertical resisting elements depend on diaphragm action for shear distribution at any level," can be interpreted as "where the horizontal bracing systems cannot be characterized as 'flexible'."

C4.4.4 Overturning

The section is taken from the UBC Section 2312(f). Other approaches have been proposed such as that in the NEHRP and ANSI A58.1.

C4.4.5 Orthogonal Effect

This provision is similar to the NEHRP provisions and is currently used by the Veterans Administration. Vertical elements at or near the corners of buildings are a typical example of a component that is utilized in both directions and would be affected by this provision. For conventional rectangular buildings with horizontal and vertical framing, the beams, girders, diagonals of individual braced frames, and shear walls not continuous with orthogonal walls are examples of components that are utilized in only one direction for seismic resistance. It is not the intent of this section to require a great amount of extra calculation.

Although the direction of force is critical for some types of structures, such as four legged towers, independent analysis on the two principal axes is sufficient for buildings, given the special provision in this section for combining orthognal load effects.

C4.4.6 Vertical Motion Effect

No provision for vertical motion is in the UBC. Similarly, no analysis is provided for the vertical motions of ground shaking in these guidelines, except for the approximation introduced in this section for cantilever members and prestressed members. This approximation provides some degree of conservatism for members that might be particularly sensitive to the effects of vertical motion and is one that is being currently used by the Veterans Administration.

More sophisticated provisions are contained in the NEHRP Provisions.

C4.4.7 Displacements

The amplification of the displacements by 3.0/K is different than in the UBC, which specifies 1.0/K. The SEAOC Commentary states that the real displacements are likely to be about 3.0/K, and the UBC uses this factor in some provisions. As explained in Section C3.1.4, the amplification by 3.0/K is used throughout in these guidelines, but 3.0/K shall not be less than 3.0.

C4.5 ANALYSIS OF OTHER STRUCTURAL ELEMENTS

This section is taken from 2312(g) of the UBC except for the minimum interconnection force, which is taken from the NEHRP.

C5. DESIGN AND CONSTRUCTION STANDARDS FOR STRUCTURAL MATERIALS

These guidelines make reference to widely accepted national standards for design and construction provisions for specific structural materials. This is in keeping with both the current practice of Federal agencies and Federal policy as set forth in Circular A-119 of the Office of Management and Budget. In many instances the materials' provisions in the UBC are derived from these same national standards. Thus, the application of this chapter should produce results similar to present practices and to the UBC.

The provisions of these guidelines frequently modify or take exception to the referenced standards, in which cases these guidelines shall control (for example, most of the provisions of chapter 6). With the exception of the standards for masonry, the references are listed such that the designer or contractor will make use of each standard as it is applicable. As discussed in C5.4, these guidelines allow some choice between different standards for masonry.

The set of standards referenced does not form a complete set of standards for construction or for structural design. Only those standards which would fulfill some need in carrying out the provisions of these guidelines are referenced. In some instances the standards referenced here may conflict with other standards referenced by Federal agencies. For issues concerned with seismic safety, priority should be given to these guidelines and their references. The editions listed for each standard are the latest available at the time of development of these guidelines. Revisions to these editions should be examined by designers and designated authorities on a timely basis.

C5.1 STEEL

The "Design Manual for Floor Decks and Roof Decks" published by the Steel Deck Institute does not provide allowable diaphragm shear values for steel deck diaphragms. It is expected that the Steel Deck Institute will soon adopt a standard design manual for diaphragm construction that would include such values; however, until such a document becomes an accepted standard, the Tri-Services Manual is an available source of design values for steel deck diaphragms.

C5.4 MASONRY

There is more regional diversity in the design and construction practices for masonry than for other construction materials. Therefore, the standards referenced for masonry tend to overlap more than the standards referenced for other materials. The UBC is widely used in the West but rarely used in the East, where the standards of ANSI, ACI, NCMA, and BIA are more widely used. Although uniformity has some positive aspects, uniformity in masonry practices will not be accomplished by theseguidelines alone. It is expected that current regional practices will continue under this standard, although a general preference for the UBC is expressed for use in the higher zones, regardless of the geographic region.

C6. STRUCTURAL DESIGN DETAILS

The details of proportioning, reinforcing, and connecting structural members are of extreme importance in achieving successful performance in earthquakes. This is because the details have an enormous effect on the capability of the seismic force-resisting system to dissipate energy through ductility and damping. Five widely accepted standards for structural detailing for seismic performance are referenced at several points in this chapter. The referencing is consistent with the philosophy expressed in C5 and it has the added benefit of brevity in theseguidelines. The designer need not have all five references on hand. Because they are required by Chapter 5, he would already have the standards of ACI and AISC on hand. The UBC, SEAOC, and Tri-Services Manual are always used as alternates, so no more than one is absolutely necessary. UBC is referenced here because of its familiarity to those experienced in seismic design and because of the convenience of its self-contained nature. SEAOC is referenced because it is the original source of much seismic provisions of the UBC and because it is accompanied by a valuable commentary. The Tri-Services Manual is referenced because of its unique treatment of several levels of performance for ductile moment-resisting frames of reinforced concrete.

C6.1 MOMENT-RESISTING FRAMES

This section is taken from Section 2312(j)1 of the UBC.

C6.1.2 Concrete Frames

Unless the actual drift is substantially less than the maximum allowable drift, the repeated distortions imposed on a concrete frame, whether it is a part of the seismic force-resisting system or not, are likely to cause substantial cracking and spalling of the concrete. Thus, any concrete frame used in the seismic force-resisting system needs the reinforcement required for ductile moment-resisting frames in order to maintain its integrity. Likewise, any concrete frame on the exterior of a building needs the same reinforcement to prevent spalling hazardous large chunks of concrete unless that building has a very stiff seismic force-resisting system.

C6.2 STEEL DUCTILE MOMENT-RESISTING SPACE FRAMES

This section is based on 2312(j)1F of the UBC. The following table summarizes the appropriate K factor, and thus the category of the seismic force-resisting system, for the two common types of steel frames used as seismic force-resisting systems:

	Zone			
	1	2(I=1)	2(I>1)	3&4
Steel frame in compliance with section 2722 of the UBC	0.67	0.67	0.67	0.67
Ordinary steel frame with joints meeting AISC Type I	0.67	0.67	1.0	1.0

C6.3 REINFORCED CONCRETE DUCTILE MOMENT-RESISTING SPACE FRAMES

This section is based on 2312(j)1F and 2625(e) and (f) of the UBC. The following table summarizes the appropriate K factor for three types of reinforced concrete frames:

	Zone				
	1(I=1)	1(I>1)	2(I=1)	2(I>1)	3&4
Highly ductile frame meeting section 2626 of the UBC	0.67	.67	0.67	0.67	0.67
Moderately ductile frame meeting 6.3.1 and 6.3.2 **	0.67	.67	0.67	*	*
Ordinary frame meeting ACI 318 without Appendix A	1.0	*	*	*	*

* system not permitted
** the UBC specifies a different K factor for this system, K = 1.0.

C6.4 BRACED FRAMES

These requirements are taken from 2312(j)1G and 2627(b) of the UBC; the only difference is in the application of the requirements in zones 1 and 2. Higher member and connection capacity is called for braced frames to assure the necessary ductility and to reduce the possibility of non-ductile connection failures.

It is possible to construct braced frames with diagonal members that are ineffective in resisting compression due to their extreme slenderness. Repeated inelastic straining of such frames leads to very large deflections because each cycle causes a net increase in the length of the diagonals; the phenomenon is often called "slap-back." Depending on the type of structure, this behavior may be very undesirable. The NEHRP provisions effectively prohibit such bracing systems for buildings over two stories in the highest seismic zones by requiring that the compressive strength of members in braced frames be at least 50 percent of the required tensile strength.

C6.4.1 Required Capacity

The term "full capacity" means the true failure load for the member. Thus strain hardening should be taken into account.

C6.5 REINFORCED CONCRETE SHEAR WALLS

This section is taken from 2312(j)1H of the UBC, except that it is not applied to the lower seismic zones.

C6.6 REINFORCED MASONRY WALLS

The table of minimum reinforcement in masonry walls is taken from the Tri-Service Manual and the seismic regulations of the Veterans Administration. It is not identical to the UBC.

C6.7 DIAPHRAGMS

This section is based on 2312(j)2D and 3A of the UBC, with significant simplification that is in accord with current practice. The need for these requirements was demonstrated by several failures in the 1971 San Fernando earthquake.

C6.8 OPENINGS IN SHEAR WALLS AND DIAPHRAGMS

This requirement is roughly based on a similar requirement in the ATC provisions. The importance of providing continuity in the chords of plate-like elements is often overlooked.

C6.9 CONCRETE AND MASONRY ELEMENTS

This section is taken from 2312(j)2B and 2310 of the UBC.

C6.10 FOUNDATIONS

C6.10.1 Ties Between Foundation Units

The provision for pile caps is taken from 2312(j)3B of the UBC; the provision for spread footings is original. In both cases the concerns are to assure that the foundation transmits the ground motion uniformly to the structure and to allow adjacent foundation units to participate in sharing lateral force overloads.

C6.10.2 Pile Cap Connections

The NEHRP provisions require the connection between the pile cap and the pile to be reinforced. One reason for a minimum tensile capacity, separate from consideration of overturning resistance, is vertical ground motions. The requirement given in this section is roughly equivalent to the NEHRP requirements, but it is stated in a performance-oriented fashion rather than in a series of prescriptive requirements for various types of piles.

C6.10.3 Concrete Piles

In addition to the need for tensile capacity implied by the preceding section, piles also need a minimum level of ductility, particularly near the top. Once again, these provisions are similar to the NEHRP provisions, although they are less detailed. Note that some types of metal casing might substitute for one type of reinforcement, but not the other. Some corrugated casings might fulfill the function of the transverse reinforcement without fulfilling the function of the longitudinal reinforcement.

C7 NONSTRUCTURAL DESIGN REQUIREMENTS

C7.1 ANCHORAGE FOR INERTIAL FORCES

This section is based on 2312(g) of the UBC. One difference is that consideration of nonstructural components has been separated from structural components in this document. The ATC provisions give some guidance on ducts and piping that are small enough so that special seismic restraints need not be designed. The Tri-Services Manual and the General Services Administration's Design Guidelines for Earthquake Resistance of Buildings both gives specific recommendations for the anchorage and protection of nonstructural components.

C7.2 DISTORTION COMPATIBILITY FOR EXTERIOR PANELS

This section is the same as 2312(j)3C of the UBC. In discussing a similar provision, the SEAOC Commentary notes that the force specified for fasteners attaching the connector to the panel or the structure shall be taken in any direction, not just horizontal, and that it need not be combined with other forces.

C7.3 PROTECTION AGAINST SECONDARY HAZARDS

This provision is based on a similar provision in the ATC.

C7.4 FUNCTIONALITY OF ESSENTIAL ELEMENTS

This provision is also based on a similar provision in the ATC. Full consideration of design for functional capability immediately following a major earthquake is beyond the scope of this standard.

C7.5 REINFORCEMENT OF CONCRETE AND MASONRY

This section is the same as 2312(j)3C of the UBC. It requires the same minimum reinforcement in zones 3 and 4 for nonstructural components as 6.9.1 does in zones 2, 3 and 4 for structural components.

C8 CONSTRUCTION QUALITY CONTROL

This chapter is loosely based on section 306 of the UBC. The intent is to cover those items whose successful performance in an earthquake is strongly dependent on sound quality control. It is not the basis for a complete quality control program, but should supplement existing agency programs.

C8.2 REQUIRED SPECIAL INSPECTION

In identifying the needed special inspection, the standard follows the UBC particularly closely. Although there is no universal agreement on the subject of special inspection, there is no intent to create new problems with this standard. It should be noted that continuous special inspection is not synonymous with full-time inspection.

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11. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here*)

This document has been prepared as a coordinated adaptation of existing voluntary standards, model building codes, Federal regulations, and research reports for use by Federal agencies. The technical content is similar to the seismic requirements of the 1985 Uniform Building Code (UBC). However, there are instances of substantive difference from the UBC. Several important provisions have been incorporated from other sources considered in this adaptation. For example, the seismic zone map is the one in current use in ANSI A58.1-1982 Minimum Design Loads for Buildings and Other Structures. A number of provisions have been added to these guidelines that are based on the current practices and policies of various Federal Agencies. Furthermore, in the spirit of improvement, this document is organized considerably differently from the UBC and many provisions are phrased differently.

12. KEY WORDS (*Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons*)

Building codes; minimum design loads; seismic; voluntary standards.

13. AVAILABILITY

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Mr. Lyons. This activity which has been going on for some time and which we discussed last year, and you recall the discussion that I think you and I had about balancing within the Federal agencies on these provisions, that activity is now complete and FEMA has submitted this set of documents to the OMB for processing as an Executive Order.

The second activity is the work done with the Building Seismic Safety Council, based on earlier work by the Applied Technology Council back in 1978, a very long project. This has now resulted in a three volume document on recommended provisions for seismic regulations for new buildings and that was published last year with some considerable publicity.

Turning to NBS research activities, I want to touch on three things that we have done in our laboratories. First, is the first phase of a study on masonry sheer walls. These are unreinforced hollow block walls. Those research results are in and we will be submitting those to the American Concrete Institute and the American Society of Civil Engineers for processing by their standards groups. We will go on to a second phase of reinforced masonry sheer walls.

We now have active in the laboratory a program on diagonally braced steel frame construction for which we use our tri-directional test facility, and the most spectacular thing I guess we have done in this business, we conducted the first experiment on last fall, which was the testing to failure of a full scale bridge pier designed according to the State of California's specifications and done under support from that state and the Federal Highway Administration. This bridge pier was 5 feet in diameter and 30 feet high. It was tested with a 12 million pound test machine with a full design load on it and using up to 2 feet lateral displacement with a hydraulic actuator against a reaction wall. The failure was interesting and somewhat spectacular.

We are going to break at least one more of those large piers if we can figure out how to get rid of the first one, which is still with us unfortunately.

We have also done a series of one-sixth scale models and the purpose of the full scale experiment was to verify our predictions as to the nature of this failure. So we will be breaking one more of those during the coming year.

A special activity that we have conducted under the guidance of the Policy Coordinating Committee of the four agencies you see before you, is a study of the National Earthquake Testing Facility, a facility discussed in the 1984 report from the National Research Council. This is for full scale testing facilities including perhaps a very large shake table.

The Policy Coordinating Group defined a four phase approach to this question, phase one of which was the definition of a research agenda for such a facility. In working with many, many different people from the community and with another review committee appointed by the National Research Council, we now have phase one complete. This is a report by Messrs. Scribner and Culver of NBS but the work really of very many people, titled "The National Earthquake Engineering Experimental Facility Study, Phase I, Large Scale Testing Needs."

With your permission, Mr. Chairman, I'll submit this for the record.

[Information to be furnished follows:]

National Earthquake Engineering Experimental Facility Study

Phase One - Large Scale Testing Needs

Charles F. Scribner

Charles G. Culver

Center for Building Technology
National Bureau of Standards
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ABSTRACT

This report summarizes information obtained during the first year of a four-year feasibility study for a national earthquake engineering experimental facility. A five-year research program is presented for a national facility in which full-scale or large-scale structures or structural components would be subjected to static or dynamic lateral loads. The facility would have applicability to tests in the following areas: low-rise buildings, medium-rise buildings, high-rise buildings, industrial processing facilities, and power facilities. Representatives from a broad spectrum of professional, industrial, and trade organizations and Federal agencies participated in developing the research program. A comparison of existing testing facilities in the U.S. and other countries engaged in seismic testing and a discussion of international cooperation in large-scale testing are included.

Keywords: Buildings, Earthquakes, Laboratories, Research, Structural engineering, Tests

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EXECUTIVE SUMMARY

This report presents results obtained during the first year (Phase I) of a four-year study to obtain the data needed to compare the cost-effectiveness of alternative methods of obtaining needed full- or large-scale experimental data on seismic response of structures. During Phase I of the study the objective was to determine existing experimental needs for large-scale testing. This study was initiated in 1985 by the National Bureau of Standards following a recommendation in 1984 by the National Research Council that the Federal government undertake planning aimed at establishing the feasibility of a major national earthquake engineering experimental/test facility.

During Phase I of the study, needs for full-scale seismic testing were determined by a broad spectrum of practicing professionals, researchers, industry representatives, building officials, and Federal agency representatives. Consulting engineers developed initial recommendations (5,6,7,8,9,10). These initial recommendations were refined at a workshop held by the National Bureau of Standards in Gaithersburg, Maryland in November 1986. Five areas in which testing needs were identified included: low-rise, medium-rise, and high-rise buildings, industrial processing facilities, and power facilities. Specific tests were recommended which made up a three- to five-year testing program.

The testing needs highlight several general problem areas requiring full-scale testing for each category. For low-rise buildings (5), for example, the interaction between roofs and walls, connection behavior, and the behavior of nonstructural elements are important. In medium-rise buildings (6), tests of buildings of the type built in low seismic risk areas, ground motion isolation devices, and the contribution of nonstructural elements to lateral stiffness and strength need to be studied. The key issues for high-rise buildings (7) are the redistribution of forces in the structure following localized yielding, the significance of second-order P-delta effects, and the force distribution in dual systems. Tests of tank structures, pressure vessels and piping, and the effectiveness of retrofit measures are important for industrial process facilities (8). Qualification tests and tests of unique components for which small-scale test data is difficult to extrapolate to full scale are needed for power facilities (9).

In addition, the workshop participants concluded that:

* There are significant needs for information about structural behavior during earthquakes that can be best satisfied by full- or large-scale testing.

- Detailed estimates are needed to determine the configuration and cost of a large facility capable of performing the required tests.

- Comparisons of the relative costs and benefits of alternative methods for conducting the tests are needed.

One critical issue is the lack of large-scale testing facilities in the United States. A comparison of testing facilities in the U.S. and other countries engaged in seismic testing indicates that the facilities of the U.S. generally are smaller and less adequate than those of Japan, which has the most complete facilities of any nation in the world for seismic experimentation. Although there have been several cooperative experimental research programs in which the U.S. and Japan have shared results, the consensus in the U.S. is that the facilities of the Japanese should not be viewed as a permanent substitute for adequate facilities in this country.

Direct and indirect benefits will be derived from construction and use of a national facility to conduct large-scale seismic testing. Direct benefits applicable to U.S. construction include methods for identifying existing buildings that need strengthening to improve their earthquake resistance, identification of economical methods for strengthening buildings, an ability to improve design procedures for future construction, and an ability to perform proof-testing of critical components of power and industrial facilities. It was estimated that data from full-scale tests of high-rise buildings could save as much as 2-3% of the cost of the structural system. This information will also have direct benefits in terms of making the U.S. competitive in international markets. It will insure that the U.S. is among the world's leaders in marketing engineering services and seismic-resistant structures and equipment.

INTRODUCTION

BACKGROUND

In 1984 the National Research Council (NRC) published the results of its 6-month study on "Earthquake Engineering Facilities and Instrumentation" (1) requested by the Office of Science and Technology Policy (OSTP). The report contained a number of conclusions, including the following:

- "There is near unanimity within the earthquake engineering community that a need exists for data on the behavior of earthquake-excited full-scale multistory structures from the initiation of structural damage to collapse.
- "The irreducible need for full-scale data on the behavior of earthquake-impacted multistory structures requires that the nation have experimental facilities able to test such structures across a range from damage initiation to collapse. At present, no adequate facilities for testing full-scale structures exist in the United States. A variety of alternative experimental/test facilities have been proposed. These include shaking tables, reaction walls, instrumented buildings in earthquake-prone areas, explosive tests, and tests on prototype structures.
- The federal government should immediately initiate a conceptual engineering design study of a national earthquake engineering experimental/test facility capable of both dynamically and statically testing full- or nearly full-scale multistory buildings to destruction in a simulated earthquake environment. The engineering design study should focus on a large shaking table of a size substantially larger than is now available in Japan. The engineering design study for the large shaking table should be used as a source of data for making a careful comparison with alternative full- or nearly full-scale methods of obtaining the needed experimental data."

One of the major recommendations of the report with regard to the latter conclusion was that "The federal government should undertake, on an accelerated basis, planning aimed at developing a major national earthquake engineering experimental/test facility. The goals of that facility should be to provide the data and understanding necessary for rapid improvement in the design and construction of seismic-resistant structures."

The Science Advisor to the President urged the Federal Emergency Management Agency (FEMA) to initiate the planning study called for in the NRC report and to obtain information which could be used as the basis for a decision on the need for and the requirements of a national earthquake engineering experimental facility. To respond to this request, this study was included in the five-year plan for the earthquake hazard reduction program for fiscal years 1985-89 (2) as Objective 5 of the program on Seismic Design and Engineering Research.

At the request of FEMA, the Policy Coordination Group (PCG) of the National Earthquake Hazards Reduction Program (NEHRP) considered the scope of a planning study and the alternatives for funding the study. On the basis of these deliberations, the PCG recommended that the National Bureau of Standards (NBS) proceed with the planning study.

The National Bureau of Standards and FEMA negotiated an interagency agreement in 1985 (3) in which FEMA agreed to provide principal funding and overall guidance and direction to the management of the study. NBS assumed responsibility for management and technical content of the study and agreed to coordinate with FEMA, NSF, and USGS throughout the study. NBS initiated the study in 1985 and developed a plan for a four-year study (4) covering all aspects of planning for a national experimental facility, including research needs, facility characteristics, siting, and management.

The information in this report is part of the four-year study; it contains recommendations for testing developed during the first year (Phase I) of the study. Objectives of the first phase of the study were to determine critical data needs on full-scale structural behavior and development of the requirements for a facility to conduct the program of testing required to satisfy those needs. Subsequent phases of the study are intended to produce a preliminary design and cost estimate for a large shaking table and reaction wall (Phase II), information on cost-effectiveness of alternative types of facilities which could satisfy the testing needs (Phase III), and recommendations for the siting, operational, and management requirements for a proposed facility (Phase IV).

OBJECTIVES

The objectives of the first year of the study were to determine the needs of users for a national earthquake engineering experimental facility, to develop an experimental laboratory-based program of three to five years duration for the facility, and to identify the benefits to be gained by the nation, the engineering profession and the building community from such a facility.

It should be noted that not all tests required to study behavior of all types of buildings under seismic loading can be conducted in a laboratory environment. For obvious reasons, tests of full-scale, high-rise buildings or of other very large structures cannot be conducted in a laboratory. A national laboratory facility would not be intended to eliminate in-situ testing of existing structures by eccentric or reciprocating mass vibrators, pull-back and release methods, high-explosive excitation methods, or instrumentation of buildings in areas of high earthquake risk. One objective of Phase III of the study will be to evaluate the relative advantages of alternative test methods and different types of facilities in providing the most effective and economical contributions to seismic-resistant design and construction.

SUMMARY OF PHASE ONE ACTIVITIES

The first task involved collecting background data to provide a perspective for research needs and to establish the state of experimental capabilities in the U.S. and worldwide. Previous workshops held in the United States to consider the needs for and benefits of large testing facilities were reviewed. A summary of these workshops is included in Appendix A. A summary of the state of existing experimental/test facilities in the U.S. and worldwide is given in Appendix B. Current activities of other nations engaged in testing of structures under simulated seismic loading are summarized in Appendix C.

The second task involved determining specific experimental research needs requiring facilities larger than those currently available in the U.S. These were determined through a workshop involving participation by representatives of professional, industrial, and trade organizations and Federal agency representatives. Organization of the workshop is discussed in Appendix D. The workshop recommendations are presented in Appendix E.

At the request of NBS and FEMA, the National Research Council established a panel to evaluate the procedures being used by NBS throughout this phase of the study. This panel was responsible for providing review and advice to the study. They also commented on all work plans and drafts of publications produced by NBS. In addition, the panel members attended the user needs workshop held in Gaithersburg in November 1986, commented on results of the study, and provided an independent statement of user needs on the basis of their experience and judgement.

EXPERIMENTAL NEEDS FOR LARGE-SCALE SEISMIC TESTS

The broad spectrum of needs for a national earthquake engineering experimental facility were aggregated into six areas of interest: low-rise buildings, medium-rise buildings, high-rise buildings, industrial processing facilities, power facilities, and lifelines.

No specific recommendations, for the type of testing considered in this study, were developed for lifelines at the workshop as noted in Appendix E. However, the working group which considered lifelines during the workshop did determine a need for in situ and laboratory testing to satisfy certain testing requirements for bridges and other lifeline facilities. Among these testing needs were:

- Tests of linear structural elements to examine the effects of skewed spans, joints, and impacting between elements
- Tests of various retrofit techniques on long linear elements,determination of energy absorption characteristics, and experimental verification of simplified analytical procedures for retrofit components
- Tests to determine effects of yield sequence on long linear systems
- Tests to study effects of spatially varying ground motions on response of long, multi-supported structures
- Tests to determine the effects of soil-structure interaction on response of lifeline facilities to severe ground shaking

The workshop working group considering lifelines also discussed the possibility of using several modular shaking tables to either simulate independent support motions or to act in a "ganged" format as a single large table. This concept of linking several independent tables to form one large table is an idea which could be considered as an alternative to a single large table in future phases of this study.

A summary of the testing needs in the five categories is given in Table 1. Specific recommendations for testing in the five areas are given in Appendix E. These testing needs reflect priorities determined by researchers, designers, manufacturers, builders, owners, regulators, and code writers represented at the workshop.

The testing needs listed in Table 1 indicate two key points in regard to the anticipated use of the facility. First, the facility is expected to serve the needs of the building community to provide data on performance of existing structures and to improve future construction. Second, it is anticipated that a significant amount of testing will be dedicated to evaluating non-structural items such as the equipment used in industrial or power facilities.

Several benefits would result from use of a large-scale testing facility. Experimental data are needed on the seismic resistance of existing buildings because changes in construction practices over time and degradation of material properties from as-built values make it difficult to calculate this resistance. This information would help to identify those types of structures which most need strengthening and would identify the most economical means of strengthening. Second, tests would provide data to identify improved design details for new structures. It was estimated this information could save as much as 2-3% of the cost of the structural system for high-rise buildings. Similar cost savings would probably result in other types of structures. These cost savings would offset the modest increase in building costs associated with the adoption of seismic design requirements in areas of the country which currently do not have such requirements.

The testing needs summarized in Appendix E highlight several general problem areas requiring full-scale testing for each category. For low-rise buildings, for example, the interaction between roofs and walls, connection behavior, and the behavior of nonstructural elements are important. In medium-rise buildings, tests of buildings of the type built in low seismic risk areas, ground motion isolation devices, and the contribution of nonstructural elements to lateral stiffness and strength need to be studied. The key issues for high-rise buildings are the redistribution of forces in the structure following localized yielding, the significance of second-order P-delta effects, and the force distribution in dual systems. Tests of tank structures, pressure vessels and piping, and the effectiveness of retrofit measures are important for industrial process facilities. Qualification tests and tests of unique components for which small-scale test data is difficult to extrapolate to full scale are needed for power facilities.

For the purposes of this study, only those tests which could best be performed in a central facility using reaction walls and shaking tables were considered. As noted previously, it was the objective of this phase of the study to identify the specific needs for these types of facilities. A determination of the desirability of the use of these types of facilities relative to that of alternative types of testing is intended to be made in Phase III of this study.

In order to determine the desired characteristics of a national earthquake engineering experimental facility, it was essential first to identify the types of tests needed and then to determine the capabilities of the facility needed to perform the required tests. The characteristics of reaction walls and shaking tables needed in a central facility were based on the testing needs identified in each area considered. The characteristics are summarized in Tables 2 and 3. It is important to note that current U.S. facilities are inadequate for almost all the tests recommended.

A primary objective of the first phase of the study was to develop a three- to five-year program of testing for a national experimental research facility. It is impossible at this time to specify an exact order in which tests should be conducted. Priorities established at this time would almost certainly change prior to completion of construction of a large facility. It is therefore appropriate to set forth a general series of tests. The most important test in each of the five areas of interest (those listed first in each category) should be considered to have equal priority. These tests make up the initial program of testing. The total effort required to conduct these tests, based on the estimates of time required shown in Appendix D, will be 25 project-years. This represents a realistic schedule of testing for the first five years of operation of a large facility.

TABLE 1

SUMMARY OF EXPERIMENTAL NEEDS

STRUCTURE CATEGORY	PRIMARY EXPERIMENTAL NEEDS
Low-rise Structures	Tilt-up Construction Wood-frame Residential Structures Cavity-wall Masonry Structures Light Metal Frame Office Buildings Mobile Home Anchorage Systems
Medium-rise Structures	Concrete Moment-frame Structures Steel Moment-frame Structures Structures with Base Isolation Structure with Soft Story Non-structural Components Precast Bearing Wall Structures Steel Stud and Gypsum Board Walls
High-rise Structures	Frame Tube Structures Energy-dissipating Devices Components of Dual Structural Systems
Industrial Processing Facilities	Unanchored Liquid-filled Tanks Methods of Retrofit for Existing Industrial Facilities Chemical Plant and Refinery Equipment
Power Facilities	Components of Power Plants Certification Tests of Components of Electrical Distribution Facilities Soil-Structure Interaction Electrical Transmission Towers

TABLE 2 REACTION WALL REQUIREMENTS

STRUCTURE CATEGORY	RECOMMENDED DIMENSIONS, m		SHEAR CAPACITY OF WALL, MN	MOMENT CAPACITY OF WALL, MN-m
	TEST BED (WXL)	REACTION WALL (HxW)		
Low-Rise	NO CRITICAL NEEDS SPECIFIED			
Medium-Rise	18 x 18	27 x 18	8.9	136
High-Rise*	15 x 15	24 x 15	8.9	35.6
Industrial Processing Facilities	18 x 18	L-SHAPED WALL EACH WING 12 x 18	2.2	20.3
Power Facilities	NO CRITICAL NEEDS SPECIFIED			

VALUES IN TABLE REPRESENT A SUMMARY OF MOST-SEVERE REQUIREMENTS IN EACH CATEGORY
* From Contractor's Report

TABLE 3 SHAKING TABLE REQUIREMENTS

STRUCTURE CATEGORY	TABLE DIMENSIONS X, Y, m	MAXIMUM WEIGHT CAPACITY, kN	DIRECTION OF EXCITATION	MAXIMUM ACCELERATON REQUIRED, g	MAXIMUM VELOCITY REQ., mm/sec	MAXIMUM DISPLACEMENT REQUIRED, mm	REQUIRED FREQUENCY RANGE, Hz.
Low-Rise	18 x 18	3,600	X,Y	0.6	760	560	0.2-20
Medium-Rise	9 x 9	12,900	X,Y	0.8	---	1000	0-30
High-Rise	9 x 9	8,900	Any 2 of X,Y,Z	1.0 (all)	1300 (X,Y) 500 (Z)	1000 (X,Y) 150 (Z)	0-10
Industrial Processing Facilities	20 x 20	16,000	X,Y,Z	1.0 (X,Y) 0.5 (Z)	760	250	0-30
Power Facilities	15 x 15	13,300	X,Z	1.8 (X) 0.9 (Z)	760 (X) 380 (Z)	250 (X) 100 (Z)	0-30

VALUES IN TABLE REPRESENT A SUMMARY OF MOST-SEVERE REQUIREMENTS IN EACH CATAGORY
* From Contractor's Report

EXISTING FACILITIES FOR LARGE-SCALE TESTING

In order to evaluate the need for a new earthquake engineering facility capable of conducting large-scale tests, it is important to consider the capabilities of existing facilities in the U.S. and to compare these capabilities to those of facilities in other countries. A summary of existing large-scale testing facilities worldwide is contained in Appendix B. The following major points may be noted in this summary:

1. Only approximately twenty percent of the large shaking tables in the world are located in the United States. Almost half the tables in the world, including some of the largest, are located in Japan.

2. Most of the large shaking tables in the world have been built in the last ten years. During this time, twice as many tables of all sizes have been built in Japan as in the U.S.

3. There are no shaking tables in the U.S. having an area greater than 100 m^2.

4. More than half of all the reaction walls in the world are located in Japan, and ten of those walls have been classified as large in Appendix B. Fewer than a third of all reaction walls in the world are located in the U.S., and only four of them are large.

It is clear that U.S. facilities are significantly smaller and less sophisticated than those in Japan. It is also clear, as noted in the previous section, that existing U.S. facilities are not large enough to perform the majority of the large-scale tests identified in this report.

Two possibilities for action exist: The United States can upgrade its own facilities to a level comparable to the facilities in Japan, or it can enter into cooperative agreements with groups in Japan to perform needed testing. In this light, it is appropriate to consider the scope of previous and possible future cooperation with research establishments in Japan and in other countries having experimental needs similar to those of the U.S. A discussion of the scope of previous and possible future cooperative research efforts with groups in Japan, Taiwan, and Germany is given in Appendix C.

Because facilities already exist in Japan for static and dynamic testing of large structures and other components, the use of Japanese facilities is an alternative to a large capital investment in a national facility by the U.S. The National

Research Council ad hoc committee on facilities and instrumentation recognized this fact in their report in 1984 (1), and addressed the issue as follows:

> "The Japanese presently have earthquake engineering experimental/test facilities that are substantially larger in scale and more complex in nature than those existing in the United States. Cooperative use of the Japanese facilities by U.S. and Japanese researchers has the potential to offer full-scale data without the need for a large capital investment in the United States."

The committee, however, was also quick to point out that the use of Japanese facilities should not be considered a permanent substitute for a facility housed in the U.S. and capable of responding to specific requests for testing by researchers and industry.

CONCLUSIONS

During the first phase of a study for a national earthquake engineering experimental facility, conclusions were reached regarding research needs. Twenty-three high-priority tests of large-scale structures and components were identified in five areas. The tests comprise a three- to five-year program of testing.

A comparison of U.S. facilities with those worldwide demonstrated that facilities in the U.S. are less sophisticated and smaller than those in some other countries, particularly Japan. In addition, the facilities available in the U.S. are not large enough to carry out any of the high-priority tests identified.

It was further concluded by workshop participants that the benefits to be gained from the ability to perform such testing warrant continuation of the present four-year study in order to determine how best to perform this testing. Continuation of the study should include detailed determination of the characteristics of a centralized national experimental facility or distributed national facilities and a comparison of relative costs and benefits from testing in a laboratory facility and similar testing conducted by alternative means. Siting requirements and a management plan for a national facility should be developed.

ACKNOWLEDGMENTS

NBS received assistance from several sources during the planning and conduct of this study. An interagency steering group met frequently throughout the project to evaluate progress and provide direction. This group was chaired by Dr. Arthur J. Zeizel of the Federal Emergency Management Agency and included in its membership Dr. Walter Hays of the United States Geological Survey and Dr. A. J. Eggenberger of the National Science Foundation.

The National Academy of Sciences established an advisory panel for the study under the auspices of the NAS Committee on Earthquake Engineering. The panel was chaired by Dr. James E. Beavers and included in its membership Dr. Mirhan S. Agbabian, Dr. Robert D. Hanson, Dr. George W. Housner, Dr. James O. Jirsa, Dr. William F. Marcuson, and Dr. Joseph Penzien. Dr. Riley M. Chung of the National Research Council staff provided administrative support for the panel and also provided valuable input to the interagency steering group.

The following six professional engineering firms were engaged to provide independent evaluations of research needs in the six areas of interest: Wiss, Janney, Elstner Associates, low-rise buildings (5); Henry J. Degenkolb and Associates, medium-rise buildings (6); Skidmore, Owings & Merrill, high-rise buildings (7); URS Corporation, industrial process facilities (8); John A. Stevenson and Associates, power facilities (9); and Imbsen and Associates, lifelines (10). These firms identified research needs that served as the basis for the final recommendations developed at the workshop. The success of the workshop itself was due to the enthusiastic participation of all attendees.

Dr. Joseph Reynen from the Commission of European Communities was extremely helpful in providing information on the Commission's study of European needs for a large-scale testing facility. Dr. Toshio Iwasaki, Director of the Earthquake Disaster Prevention Department of the Public Works Research Institute in Tsukuba, Japan, conducted the background study of current utilization of Japanese large-scale testing facilities. Their assistance is gratefully acknowledged.

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APPENDIX A

SUMMARY OF PREVIOUS WORKSHOPS

The benefits to researchers, designers, contractors, and manufacturers from the availability of a facility capable of subjecting large structural models or structural or mechanical components to simulated seismic loading have long been recognized. A number of workshops have been held to consider various types of facilities and the ways they could be of benefit. The following discussion summarizes relevant details of the recent workshops.

1. Potential Utilization of the NASA/George C. Marshall Space Flight Center in Earthquake Engineering Research, Earthquake Engineering Research Institute Report, December 1979.

A site visit and workshop were held at the National Aeronautics and Space Administration (NASA) facilities at The George C. Marshall Space Flight Center (MSFC), Alabama, on February 22-24, 1979. The workshop was sponsored by NSF and NASA and chaired by members of the Earthquake Engineering Research Institute (EERI). Twenty-six earthquake specialists from academia, industry, and government attended the workshop.

The thrust of the workshop was to examine the feasibility of using the unique MSFC facilities for large-scale seismic testing of both structures and soils. Suggested potential uses were cyclic static and dynamic testing of multistory structures, medium- and large-scale soil model tests to study dynamic behavior of soil masses under earthquake excitation, dynamic soil-structure interaction tests, and utilization of the NASA spacelab under near-zero-gravity environment to evaluate constitutive properties of soils under near-zero confining stress conditions. Cost data were not available to conduct cost analyses relative to any specific test requirements.

An assessment was made of the needs for and availability of large- and full-scale testing facilities in the following areas:

Cyclic Static Tests Test towers are needed to apply static cyclic horizontal loads in two directions with forces sufficiently large to test 30-m high (10 stories), 1000-ton specimens to destruction. Available facilities (the University of California at Berkeley, the PCA laboratory and the University of Texas at Austin) do not meet simultaneously these size and force requirements. A number of MSFC facilities that seem to meet these specifications should be considered. These include static and vibration test equipment in the Structures and

Mechanics Laboratory, the structural test tower, the vertical ground vibration facility, the hazardous structures test facility, and the model special test equipment.

Shaking Table A large (15 m x 15 m) shaking table with a payload capacity of 2000 tons and two-directional horizontal motion is needed to perform destructive testing of full-scale (10-story, 1-bay) structural or soil-structure models. The table would be required to have a 500 mm stroke, a frequency range of 0 to 40 Hz, and a maximum velocity of 65 cm/sec for each direction of horizontal motion. None of the available shaking tables meet these specifications. Shaking tables at the University of California at Berkeley, the PCA laboratory and NASA/MSFC are being used for testing small- or medium-scale models or 1 to 2-story, 1-bay large- or full-scale models.

Vibration Generator Sinusoidal vibration generators have been used to measure elastic, dynamic characteristics of large structures. The DOE generator at the Nevada test site and the NASA/MSFC facility (40 shakers, a 45-ton maximum payload and a maximum stroke of 225-mm) can be used to evaluate the dynamic properties of models or systems in the elastic range. A larger facility will be required to study the changing behavior of large-scale specimens in the inelastic range.

Dynamic Soil Tests The properties of soils sought are the dynamic moduli, Poisson's ratio, and liquefaction parameters. Methods used in the laboratory are the ultrasonic pulse test (to measure compression and shear waves), cyclic triaxial, direct shear and torsional shear tests to evaluate settlement and liquefaction potential, and centrifugal tests to simulate dynamic excitation. Field tests used for in-situ measurements of soil properties include seismic crosshole survey, seismic downhole survey, seismic reflection survey, electrical sensing probe, standard penetration test and horizontal polarized shear wave technique. The NASA/MSFC facilities that can be considered for soil testing include the equipment in the geotechnical laboratory for conducting static, steady-state and three-dimensional dynamic testing, and the 3.6 m-diameter centrifuge for simulating dynamic excitation. As noted before, the NASA spacelab was considered for use in soil experiments because it offered the possibility of evaluating key soil parameters without the confinement of a gravitational field.

It was concluded at the workshop that NASA/MSFC did have certain unique testing capabilities for seismic experiments. It was recommended that structural and geotechnical task committees be formed to develop large-scale test programs, taking into account priorities dictated by cost analyses of required modifications and by the unique aspects of the NASA/MSFC facilities.

2. Experimental Research Needs for Improving Earthquake-Resistant Design of Buildings, EERI Report No. 84-01, January, 1984.

This workshop was held on July 21-22, 1983 and was hosted by the Earthquake Engineering Research Institute (EERI). The purpose was to identify experimental research needs. It was sponsored by NSF and was attended by participants from academia, the private sector and the U.S. Government. The workshop focused on the following subjects:

Identification of Experimental Research Needs There was general consensus on the inadequacy of existing information on the inelastic performance of buildings in severe earthquakes. Research to determine experimentally the ultimate capacity of building systems as well as their capacity to sustain damage without failure or collapse were underscored. Important types of buildings for which full-scale tests are needed were identified. Low- to high-rise residential buildings as well as medium- to low-height commercial and industrial structures were considered. An economic analysis indicated that $20 million would be required to determine the performance of just one major type of structure. Recommendations on specific details of needed experiments were not included.

Evaluation of Experimental Methods Specific shaking table needs were cited: a 25 ft x 50 ft table having one horizontal degree of freedom; a table similar to the one located at the University of California at Berkeley but having two horizontal components of motion (instead of one vertical and one horizontal as at Berkeley); and a table large enough to test at least small structures at full scale.

It was recommended that two to three reaction wall systems be constructed, all with the capacity to apply force in three directions, and one with capacity to test structures with heights of at least 40 ft.

Requirements were identified and specifications given for a shaking table capable of applying motion in three orthogonal directions for testing small (one-quarter-scale or less) models. Some guidance was provided on the cost of construction and maintenance of such a facility.

Harmonic excitation, ambient testing and impulse loading were explored for testing of prototype structures. However, it was concluded that such tests could not take the central role in experimental research because of costs in time and money.

Two excitation methods using buried and contained high explosives for testing large soil-structure systems were discussed. These methods were considered as basic tools for earthquake experimental research because of their potential for use in evaluating the inelastic response of large structures and soil-structure systems. Cost was estimated at $900 K for testing using contained explosives. The cost of testing large structures to damaging levels was estimated to be $5 million.

Feedback from the response of instrumented buildings was considered to be key information for mathematical modelling. Therefore, it was recommended that instrumentation of existing buildings be part of a national plan for earthquake hazard mitigation. However, it was recognized that the randomness and infrequency of occurrences of strong-motion earthquakes remain a major limitation of this form of experimental research.

The workshop advanced the concept of a research consortium to coordinate all the experimental research in the U.S., and proposed a specific management plan involving sponsors, industry, universities, research institutions, the laboratory manager, and other directors, operators, and users of the laboratory.

Existing U.S. facilities were identified relative to research needs. Plans to provide new and/or expanded facilities were proposed, including modernization of existing facilities and establishment of a major national facility which would house a large (20 m x 20 m) shaking table.

3. A National Bridge Engineering Laboratory - A Proposed Plan, Center for Civil Engineering Earthquake Research (CCEER), College of Engineering, University of Nevada, Reno, December, 1984.

This report documents the proceedings of a workshop to identify earthquake research and experimental facilities needs for bridges. The workshop was sponsored by NSF and held in Reno, Nevada, on April 4-6, 1984. The participating engineering professionals were drawn from private practice, academia, and state and federal organizations. The principal topics discussed were the highway bridge problem, the solution of this problem through establishment of a National Bridge Engineering Laboratory, research needs, and laboratory management.

National Bridge Engineering Laboratory On the basis of perceived needs for research, participants in the workshop recommended the following:

- A national center for bridge engineering to promote excellence in bridge engineering, and particularly to promote excellence in design for seismic loading.

- The center should be equipped with experimental facilities for testing large- and full-scale bridges, both in the laboratory and in the field. It should also provide education, training and information services to the bridge engineering community.

The needed equipment and facilities were illustrated in ten conceptual drawings. The capital costs for the center were estimated to be approximately $100-150 million, including land acquisitions, buildings and equipment. The expenditures for operations and research activities were estimated at $20 million per year.

Research Needs A broad spectrum of experimental research was identified. Areas in which tests were recommended included large-scale experiments on multiple shaking tables, large-scale experiments using the pseudo-dynamic method, field experiments on full-size bridges, and repair and retrofit methods for existing bridges.

Laboratory Management Three aspects of management of the facility were considered during the workshop. The recommendations developed were that the laboratory should:

- be managed by a board of directors made up of representatives from all elements of the bridge engineering community

- have a managing director

- have a permanent, high-level, professional and technical staff

The management structure proposed was similar to that suggested for the earthquake engineering laboratory proposed during the EERI workshop of July, 1983.

APPENDIX B

SURVEY OF FACILITIES WORLDWIDE

The two most common types of laboratory facilities used in seismic testing today are 1) shaking tables, and 2) reaction walls. This section discusses the capabilities of existing facilities of these two types in the United States and other countries.

SHAKING TABLES

The graphs shown in figures 1 through 6 illustrate information obtained from References 1-5 and present different components of a shaking table's performance.

As illustrated in figure 1, more than half (fifty-two percent) of the seventy-nine shaking tables existing worldwide have an area less than or equal to 10 square meters. Twenty-nine of these, or thirty-seven percent of all such tables worldwide, are located in the United States.

Of those shaking tables with an area greater than 10 square meters, only seven are located in the United States. Three of these have an area between eleven and fifteen square meters. The largest electro-hydraulic shaking table in the United States is located at the Earthquake Engineering Research Center at the University of California at Berkeley and has a table area of 37.2 square meters. Shaking tables with areas greater than 100 square meters include tables at the Institute for Building Research in Romania, at the Nuclear Power Engineering Test Center in Japan, and at the National Research Center for Disaster Prevention in Japan. The world's largest table has an area of 900 square meters and is located in the USSR.

Figure 2 summarizes information about the location of large (defined here as having a table larger than 3 meters by 3 meters) shaking tables. Of the forty-seven large shaking tables worldwide, twenty-four (approximately one-half of the total) are located in Japan, nine (less than one quarter of the total) are in the United States, four are in Germany and the rest are located in those countries with two tables or less. Also worth noting in figure 2 is the category "OTHER," in which are included those countries with fewer than three large tables each. The countries with two large tables are China, USSR, Romania and Italy. Those with only one large table include France, Yugoslavia and Greece.

The time of installation of all large shaking tables is illustrated in figure 3. The majority (twenty-five) of all large shaking tables worldwide have been installed during the last 10 years (1976-1986), and most of those are located in Japan. Only four tables were installed in the United States during this period, while eleven were installed in Japan. The largest table installed in the United States during this period (at Wyle Laboratory) has an area of 33.6 square meters.

A comparison of displacement capacities of existing shaking tables is shown in figure 4. This figure illustrates the fact that the total maximum displacement of the table in any direction of motion for slightly more than half (fifty-three percent) of all existing shaking tables is less than 100 mm. Seventy-four percent of the shaking tables in Japan (a total of twenty-four) are in this category. Thirty-eight percent of the shaking tables in the United States (a total of twenty-nine) have a similar displacement capacity. Seventy-two percent of all existing tables have a capacity for maximum displacement in any direction of motion of less than 150 mm (approximately 6 inches). Of the twenty-one shaking tables with capacities for maximum displacement greater than 150 mm, eleven would be considered large by the definition given previously. Eight of these large tables are located in the United States, two are located in Japan, and one is in the USSR.

Figure 5 illustrates the distribution of horizontal acceleration capacities (assuming the table to be loaded with maximum weight) of existing shaking tables. Almost all of the tables having the capacity to apply accelerations greater than 10 g are located in the United States. Eighteen of the twenty tables capable of applying accelerations greater than 5 g are located in the United States. However, these shaking tables are too small (having table areas less than 3 meters by 3 meters) to use for seismic testing of full-scale structures. Shaking tables capable of applying accelerations less than 2 g comprise sixty-one percent of all existing tables. Seventy-three percent (nineteen out of twenty-six) of all Japanese shaking tables can apply a maximum of 1.0 g horizontal acceleration. Six tables located in Japan and four tables located in the U.S. are capable of applying maximum accelerations between 1.1 g and 2.0 g. These ten tables all could be used to conduct large-scale seismic tests.

The distribution of weight capacities of existing tables is shown in figure 6. Twenty-four shaking tables, or approximately thirty percent of those existing, are capable of carrying the weight of a full-scale structure (200 kN or greater). Three tables having a capacity greater than 200 kN are located in the Unites States (at the University of California at Berkeley, Union Carbide, and Wyle Laboratories). Thirteen, or approximately one-half of all shaking tables with weight capacities greater than 200 kN are in operation in Japan, two are in the USSR, and two are in Romania.

Shaking table testing of full-scale structures requires a table which has sufficient size, acceleration capacity, and weight and displacement capacity. As noted above, only twenty-four existing tables have a weight capacity of at least 200 kN. All of these tables can apply lateral accelerations of at least 1.0 g when loaded to their capacities. If it is also required that the minimum area of the table be 25 square meters, only approximately twenty-four percent of all existing tables meet weight capacity, acceleration capacity, and area criteria. Some other tables meet one or more, but not all, of these criteria. Of the seventy-nine shaking tables existing worldwide, more than half are limited to testing of small-scale models.

LARGE REACTION WALLS

The use of reaction walls to apply static lateral loads is perhaps the most common method of seismic testing used throughout the world. Reaction walls are defined here as large if they are greater than 10 meters high. In this section, large reaction walls will be discussed and information about these walls will be illustrated in figures 7-9.

Figure 7 illustrates the fact that more than twice as many large reaction walls are located in Japan as in the United States. There are a total of forty-seven reaction walls worldwide. Twenty-five of these walls, including ten walls more than ten meters tall, are located in Japan. Fifteen reaction walls are located in the U.S., but only four of these are taller than 10 meters.

Figure 8 illustrates the distribution of lateral shear capacities of all existing reaction walls. Sixty-three percent of existing walls have a lateral shear capacity less than or equal to 10 MN. Of these, eleven walls are located in the United States, thirteen are in Japan, three are in Australia and one is in South Africa. Twenty-nine reaction walls, or sixty-one percent of all reaction walls, have a shear capacity greater than 6 MN. Of these, six are in the United States and twenty-two are in Japan.

Seven of the twenty-two large reaction walls (greater than 10 meters high) located in Japan have a shear capacity greater than 6 MN. Two of the six large walls in the United States have lateral shear capacities greater than 6 MN. There are no walls outside of Japan that are both higher than 10 meters and have a lateral shear capacity greater than 11 MN.

The Portland Cement Association (U.S.) has two of the largest and strongest reaction walls in the world, although both walls are less than 10 meters high. The Building Research Institute (Japan) has one of the strongest and highest reaction walls in the world.

Figure 9 summarizes information about the bending capacity of reaction walls worldwide. Thirty-four percent of all existing reaction walls have bending capacities less than or equal to 10 MN-m. Nine of the fifteen walls in the United States have capacities in this range. Of all walls higher than 10 meters and having bending capacities greater than 50 MN-m, two are located in the United States and five are located in Japan.

Of the ten walls in Japan higher than 10 meters, all have a bending capacity of at least 11 MN-m. The reaction walls which have bending capacities greater than 50 MN-m and which are located in the United States include the walls at PCA (2), the National Bureau of Standards, and the Budd Corporation. The reaction walls located in Japan having capacities greater than 50 MN-m are the walls at the Sumitomo Corporation, the Ohbayashi Corporation, the Fujita Corporation, the Okumura Corporation, the Toda Institute, and at the Building Research Institute (2). There are no large reaction walls outside of Japan or the United States.

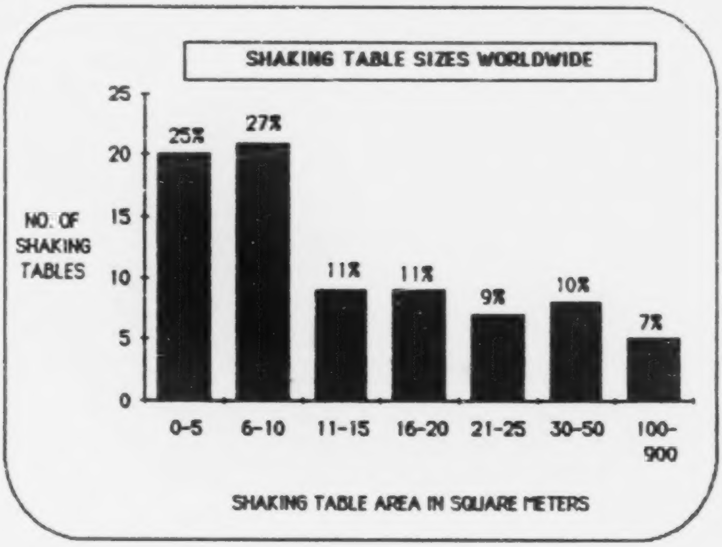
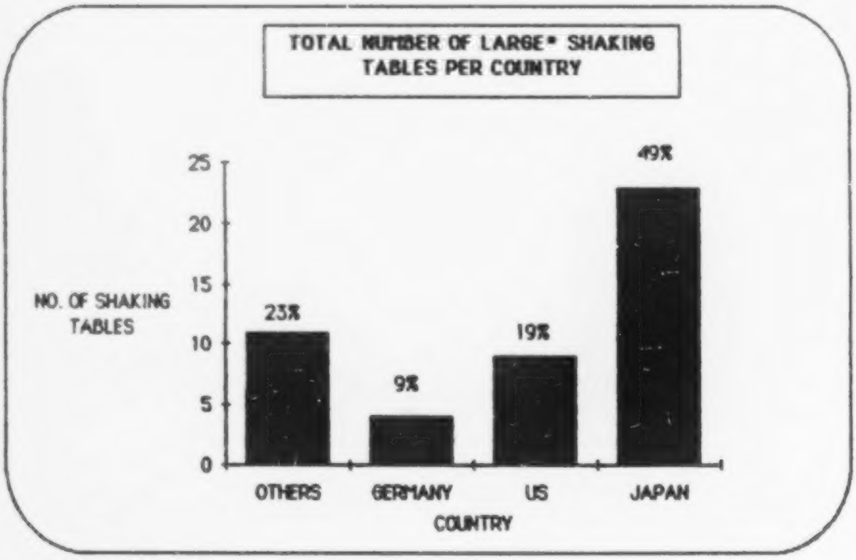


Figure 1. Sizes of shaking tables worldwide.



* TABLES > 3m x 3m

Figure 2. Location of large shaking tables.

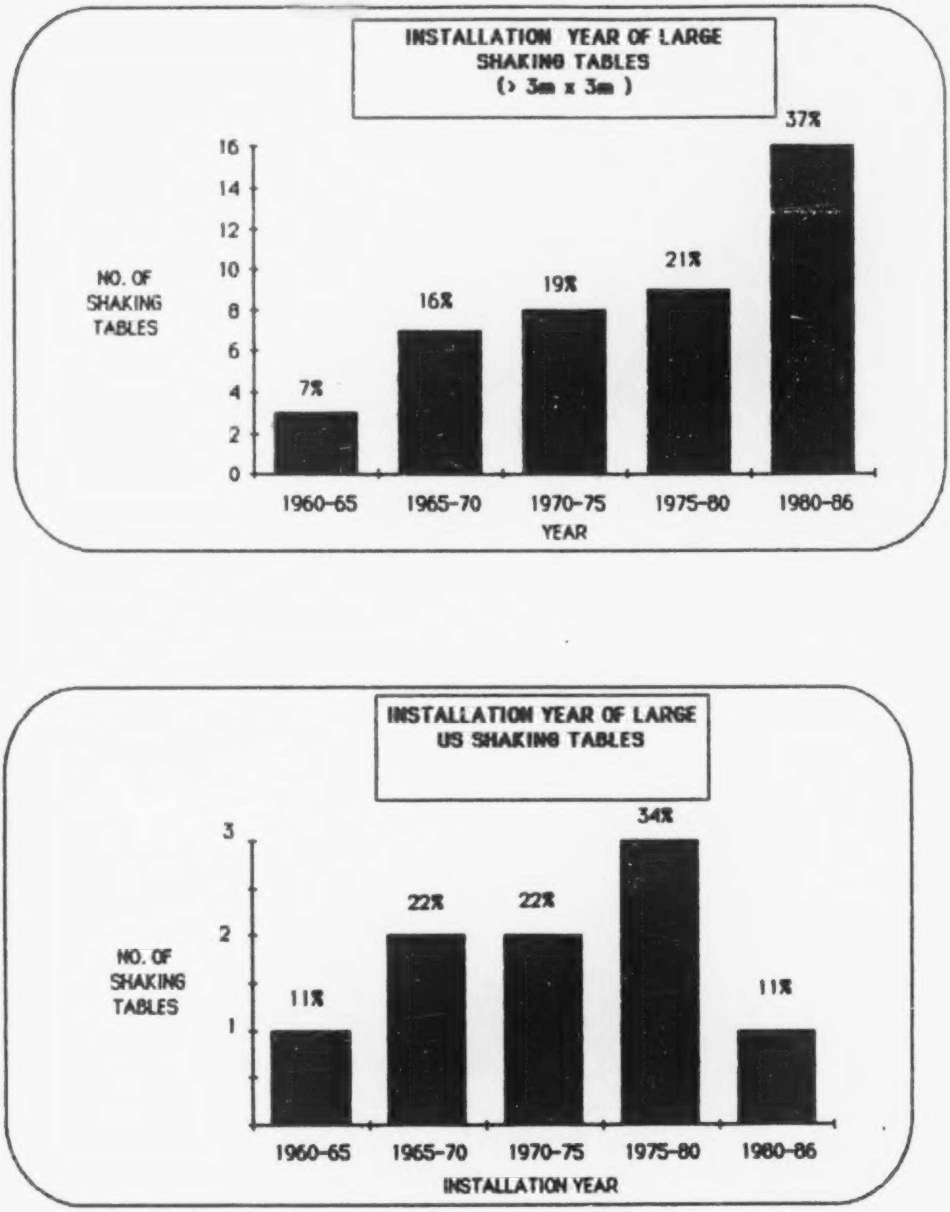


Figure 3. Year of installation of large shaking tables.

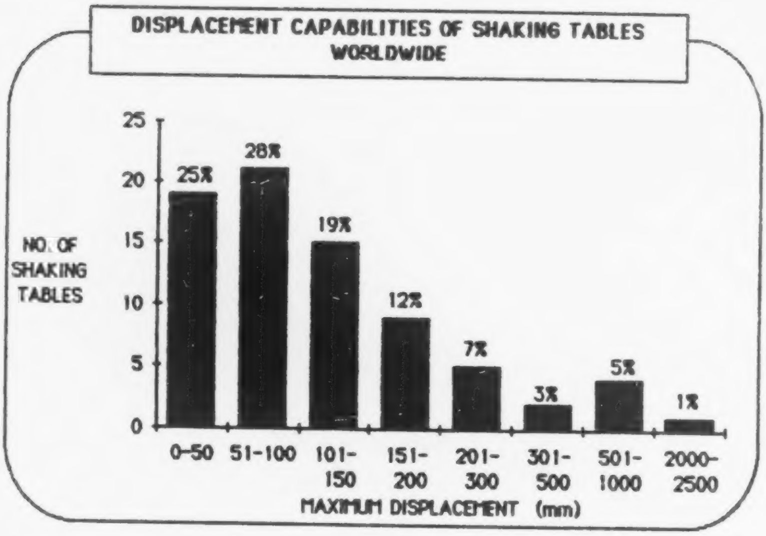


Figure 4. Displacement capacities of shaking tables.

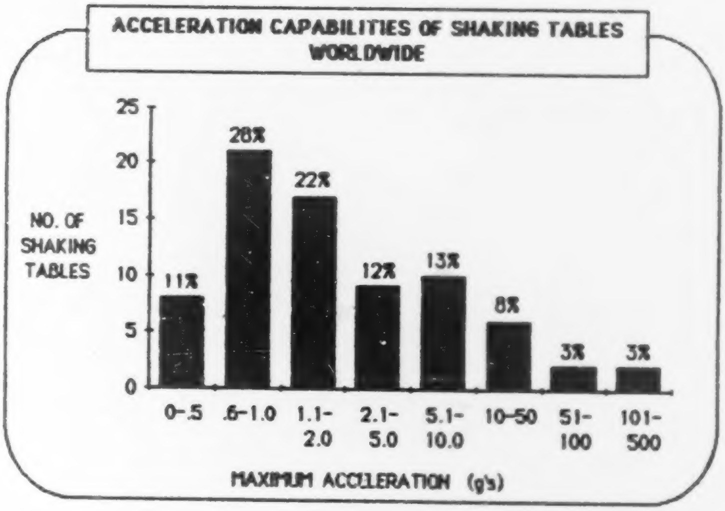


Figure 5. Acceleration capacities of shaking tables.

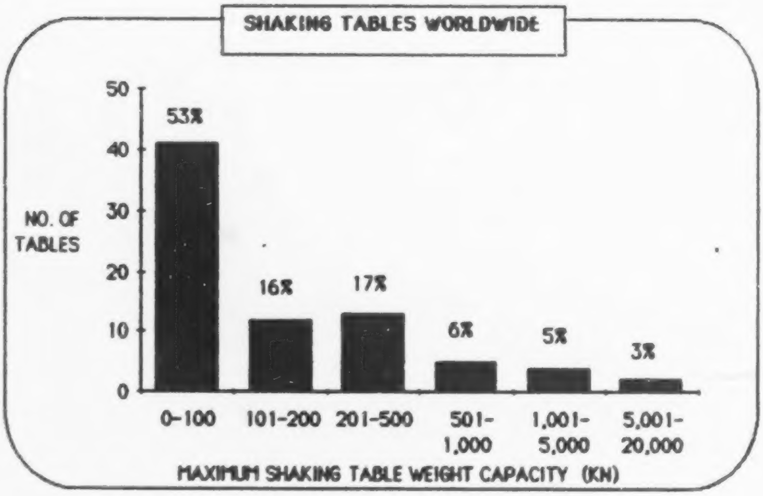


Figure 6. Weight capacities of shaking tables.

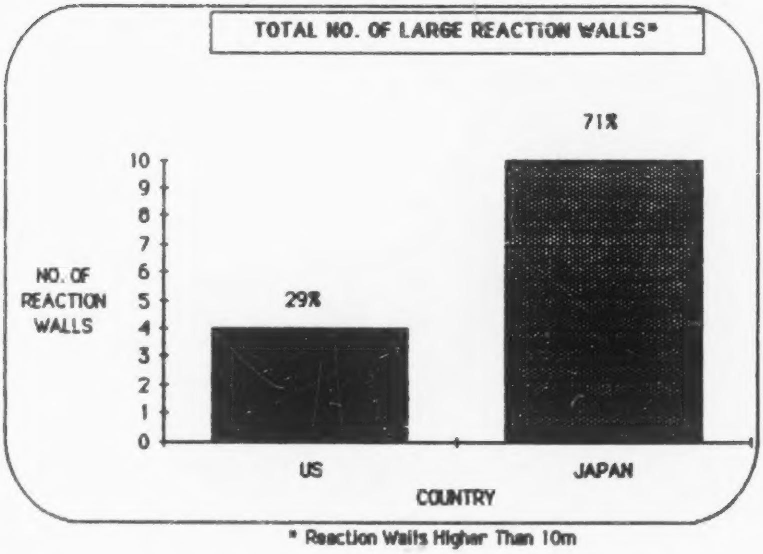


Figure 7. Distribution of large reaction walls.

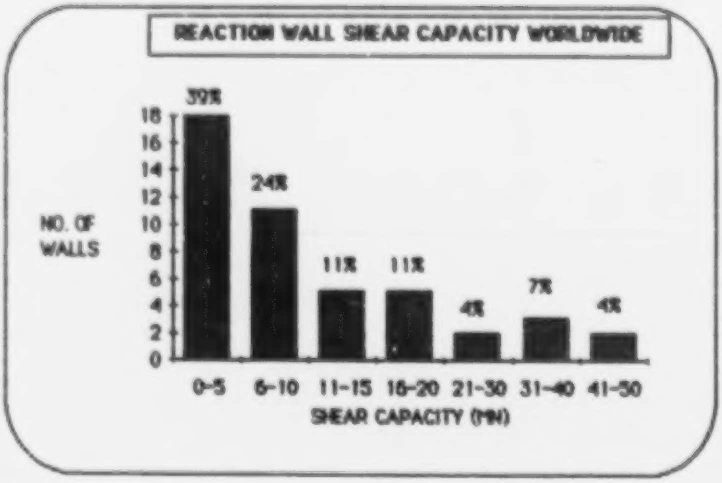


Figure 8. Shear capacities of reaction walls.

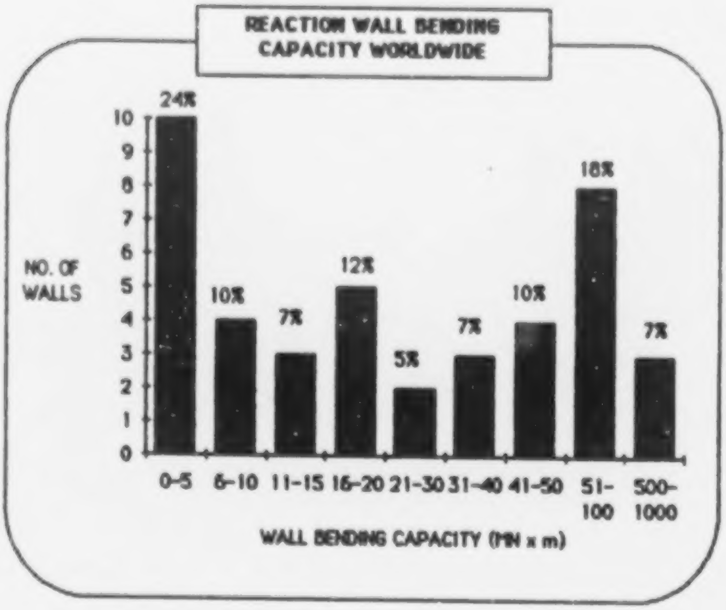


Figure 9. Bending capacities of reaction walls.

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2. Kamimura, K., Aoki, Y., and Masayoshi, N., "Kenchiku Kenkyu Shiryo", Register of World Large-Scale Test Facilities for Building Research, Report for C. I. B., No. 49, Building Research Institute, Ministry of Construction, Tsukuba, Japan, March, 1984.

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4. Stevenson, J. A.,"A Report Identifying and Describing the Needs for Seismic Research Utilizing Large or Full Scale Testing of Power Facility Structures and Equipment", Draft Report for NBS, Stevenson and Associates, Cleveland, Ohio, September, 1986.

5. "Facilities of the National Bureau of Standards", U. S. Department of Commerce, NBS SP 682, Gaithersburg, Maryland, September, 1984.

6. "Tadotsu Engineering Laboratory", Seismic Proving Tests for Large Components of Nuclear Power Plants, Nuclear Power Engineering Center, MITI, Japan, 1982.

APPENDIX C

INTERNATIONAL ACTIVITIES AND COOPERATIVE RESEARCH

FACILITIES IN JAPAN

In the process of considering the needs of the United States engineering community for a large-scale experimental facility, it was important to review programs undertaken by other countries to address their own testing needs. Also of interest was the availability of overseas test facilities for use by U.S. investigators should this approach be deemed appropriate. The information included in this appendix was obtained from a survey of the Japanese seismic testing program and from a review of a recent study conducted to determine the needs for a large testing facility in Europe.

In order to determine the availability of Japanese facilities for use by engineers in the U. S. and in countries outside of Japan, the Public Works Research Institute of Japan was contacted. Dr. Toshio Iwasaki, Director of the Institute's Earthquake Disaster Prevention Department and a member of the U.S.-Japan Cooperative Program in Natural Resources, Panel on Wind and Seismic Effects, provided information about the seismic testing resources of the Japanese government and of Japanese companies that maintain large testing facilities.

The status of large-scale seismic testing facilities in Japan is well documented. A register published in 1984 (Ref. 2, Appendix B) listed the majority of facilities currently existing in Japan and elsewhere. Since that time, three institutions listed in the register have installed either new shaking tables, reaction walls, or testing machines. In addition, some combination of shaking tables, reaction walls, and testing machines have been installed in five institutions that had not been previously listed. The institutions that have upgraded old facilities or installed new facilities are summarized in Table C1. Characteristics of all new facilities are listed in Tables C2 and C3.

The facilities available in Japan have attracted the interest of U. S. Government agencies and private firms having a need for specialized testing. Dr. Iwasaki contacted eighteen public institutions and private firms in Japan to determine the availability of their facilities to U.S. researchers and to determine if U.S. firms have discussed use of the facilities. The results of this inquiry are summarized in Table C4.

All of the organizations contacted indicated that their facilities could be made available to U.S. Government agencies. Ten of these organizations stated that they would be willing to lease their facilities to American private firms, and all of the organizations indicated that they would agree to participate in cooperative research with either private firms or government agencies from the U.S. The majority of Japanese firms are willing to negotiate the fee for use of their facilities, but the majority are also unwilling to allow outside firms more than three months to complete tests for which they lease testing facilities.

STUDY BY EUROPEAN COMMUNITIES

The number and capacity of facilities available in Japan are unequalled elsewhere in the world. The demonstrated benefits provided by these facilities have inspired engineers in countries other than Japan to investigate their own needs for similar facilities. The Commission of European Communities recently considered needs of European engineers for a large central seismic testing facility. Although the results of their study have not been reported publicly and no decisions have been made to design or construct a large regional testing facility in Europe, the study did contain the following general findings:

- Experimental verification of computer models is necessary to insure accurate idealization of structural properties and accurate prediction of structural behavior, particularly inelastic cyclic behavior.
- Small-scale experimental test facilities have significant limitations. Construction of test specimens is difficult and expensive. Because extensive extrapolation is required to relate behavior of prototype structures to that of model structures, inaccurate representation of nonlinear behavior of prototype structures is possible.
- A majority of engineers of the European community have agreed that their testing needs could be satisfied by a facility containing a large reaction wall and a shaking table with a weight capacity of 200 metric tons.

The study also noted that a factor more important than the construction of specific facilities is coordination of research activities in earthquake engineering and safety of structures through centrally designed and managed research programs.

INTERNATIONAL COOPERATIVE RESEARCH

One option to undertaking the construction of a national engineering facility is to use facilities in other countries under cooperative testing agreements. Because several facilities appropriate to the needs of some experimentalists in the U.S.

exist in other countries, the use of these facilities whenever possible could delay the need and expense of construction of a central facility in the U.S.

The National Science Foundation, through the U.S.-Japan Cooperative Program in Natural Resources and the U.S.-Japan Cooperative Earthquake Engineering Research Program, has been a major sponsor of cooperative research between the U.S. and Japan. Through these programs, U.S. researchers have participated in tests of full-scale concrete and steel structures at the Japanese Building Research Institute laboratory in Tsukuba, Japan. Cooperative research is continuing with the construction and testing of a full-scale masonry structure.

The U.S. Nuclear Regulatory Commission (NRC) and the Electrical Power Research Institute (EPRI) have also undertaken cooperative research and testing projects with groups in other countries. A brief description of these agreements follows.

One of the most attractive facilities for large-scale testing and seismic research is the Japanese Nuclear Power Engineering Test Center's Tadotsu Engineering Laboratory. The shaking table housed in that facility is designed to subject very large components of nuclear powerplants to simulated seismic loading. In 1986 the U.S. Nuclear Regulatory Commission and the Japanese Ministry of International Trade and Industry (MITI) signed an agreement to conduct cooperative tests of powerplant components. Tests of a pressurized water reactor primary coolant loop are scheduled to begin in 1988. Indications are that MITI and NRC will continue to conduct cooperative testing at the Tadotsu site for the next decade. In addition, it is possible that this initial agreement will be expanded to include structures other than powerplants after the current program of testing is completed in 1990.

The U.S. Nuclear Regulatory Commission has also begun cooperative field testing of a full-scale nuclear powerplant in the Federal Republic of Germany. In a cooperative agreement with the German ministry of power and a private German testing firm, NRC is using a decommissioned nuclear reactor in Karlsruhe as a testbed for vibration testing. To date a large eccentric shaker has been mounted in the plant in order to determine natural frequencies of vibration of the plant and its components. Higher-level shaking tests of piping and other components are scheduled to begin in the coming year, and additional tests are planned through 1990.

In a third program of cooperative testing, NRC, the Electrical Power Research Institute and the Taiwan Power Company have begun to study soil-structure interaction. In these tests, a large simulated powerplant foundation and structure have been constructed in a seismically active region in Taiwan. Various forced vibration tests have been conducted on this testbed. Instruments have been placed to measure free-field vibrations from natural earthquakes and to measure the response of the foundation and structure during these earthquakes. This is perhaps the most comprehensive program of testing ever conducted to study soil-structure interaction in connection with a structure of this type on natural soil. To date the site has been shaken by four large earthquakes and valuable data have been gathered. This program promises to be very valuable and relatively inexpensive for all involved. Because the use of the site is dependent in some aspects on naturally occurring earthquakes to provide seismic input, it is impossible to schedule all tests precisely or to know in advance of any shaking how severe the shaking will be. This program of research is expected to continue for several years.

TABLE C1

RECENT ADDITIONS TO AND UPDATES OF JAPANESE FACILITIES

INSTITUTION	FACILITY INSTALLED		
	TEST BED AND REACTION WALL	UNIVERSAL TEST MACHINE	SHAKING TABLE
Public Works Research Institute Ministry of Construction (PWRI)	X	X	X
Shimizu Construction Co. Ltd. Research Laboratory (SHIMIZU)			X
Ohbayashi-Gumi, Ltd. Technical Research Institute (OHBAYASHI)			X
Nippon Telegraph and Telephone Corporation, Tsukuba Engineering Development Center (NTT-TEDC)	X	X	
Okumura Corporation Tsukuba Research Institute (OKUMURA)	X	X	X
Toda Institute of Construction Technology (TODA)	X	X	
Japanese National Railroad Technical Research Institute (JNR)			X
Central Research Institute of Electric Power Industry, Civil Engineering Lab. (CRIEPI)			X
Institute of Industrial Science University of Tokyo (IIS)	X	X	X

TABLE C2

CHARACTERISTICS OF REACTION WALLS RECENTLY INSTALLED IN JAPAN

INSTALLATION	YEAR INSTALLED	DIMENSIONS, m		WALL SHEAR CAPACITY MN	WALL BENDING CAPACITY MN x m
		TEST BED L x W	REACT. WALL H x W		
PWRI	1980	15 x 20	5 x 15 (2) 5 x 20 (2)	6	19.2
NTT-TEDC	1980	15 x 15	6 x 8	16	16
OKUMURA	1985	14 x 19	12 x 13	22	110
TODA	1982	15 x 10.6	10 x 10.6	15	100
IIS	1983	10.5x10.5	7 x 10.5 7 x 16.0	9.1	14.7

TABLE C3

CHARACTERISTICS OF SHAKING TABLES RECENTLY INSTALLED IN JAPAN

INSTALLATION	TABLE DIMENSIONS m	WEIGHT CAPACITY kN	DIR. OF EXCITATION (Z = vert.)	MAXIMUM ACCEL. g	MAXIMUM VELOCITY mm/s	MAXIMUM DISPLACEMENT mm	FREQUENCY RANGE Hz
PWRI	8 x 6	1000	X,Z	2.5 g(X) 1.25 g(X)	600 (X) 300 (Z)	75 (X) 37.5 (Z)	0 - 30
	3 x 3 (x4)	250 (x4)	X	2.5 g	600	75	0 - 50
SHIMIZU	4 x 4	200	All DOF	0.8 g	1000 (X,Y) 500 (Z)	200 (X,Y) 100 (Z)	0 - 50
OKUMURA	4 x 4	600	X,Y,Z	3.0 g	1000 (X,Y) 500 (Z)	125 (X,Y) 75 (Z)	0 - 70
JNR	12 x 8	2000	X	0.4 g	400	400	0 - 20
OHBAYASHI	3.5 x 6.6	500	X	1.0 g	500	100	0.1 - 50
IIS	3 x 3	70	X,Z	2.0 g(X) 1.1 g(Z)	750 (X) 350 (Z)	150 (X) 60 (Z)	0 - 50
CRIEPI	8 x 3	1000	X	0.8 g	500	300	0 - 5

TABLE C4

AVAILABILITY OF JAPANESE FACILITIES FOR U.S. USE

INSTITUTION	AVAIL. FOR U.S. GOV'T. AGENCY, CONDITIONS FOR USE	AVAIL. FOR U.S. PRIVATE FIRMS, CONDITIONS FOR USE	U.S. ORGANIZATIONS HAVING USED OR CONSIDERING USE	FACILITY USE		TYPES OF STRUCTURES TESTED
				RESEARCH	NON-RES.	
BRI	AVAILABLE (1,a)	AVAILABLE (5,1,a)	NSF, UNIVERSITIES	90 %	10 %	BUILDINGS
KAJIMA	AVAILABLE (4,a)	AVAILABLE (1,4,a)	PRINCETON UNIV. UNIV. OF HOUSTON U.C. BERKELEY	40 %	60 %	BUILDINGS SUBASSEMBLY INSTRUMENTS
KAWASAKI	AVAILABLE (3,a)	AVAILABLE (3,a)	NONE	40 %	60 %	STEEL STRUC
KYOTO U.	AVAILABLE (3,FREE)	AVAILABLE (5,3,a)	NONE	100 %	0 %	ALL TYPES
NRCDP	AVAILABLE (3,a)	AVAILABLE (5,3,a)	NSF, STANFORD U.	70 %	30 %	ALL TYPES
NUPEC	AVAILABLE (4,a)	AVAILABLE (5,4,a)	NRC,BROOKHAVEN LAB	50 %	50 %	NUCLEAR POWER
OHBAYASHI	AVAILABLE (4,b)	AVAILABLE (1,a)	NONE	40 %	60 %	BUILDINGS
CRIEPI	AVAILABLE (1,a)	AVAILABLE (5,1,a)	NONE	80 %	20 %	PIPELINES, SOIL-STRUCT
SUMITOMO	AVAILABLE (4,b)	AVAILABLE (4,b)	NONE	50 %	50 %	NUCLEAR, BRIDGES

AVAILABILITY CODES:
1 TIME SCHEDULE NEGOTIABLE
2 MAXIMUM OF 2 MONTHS USE ON ANY PROJECT
3 MAXIMUM OF 3 MONTHS USE ON ANY PROJECT
4 TIME SCHEDULE ADJUSTABLE, DEPENDING ON INTERESTS OF INSTITUTION
5 FACILITY AVAILABLE TO PRIVATE FIRMS ONLY FOR JOINT RESEARCH

a FIXED FEE SCHEDULE FOR USE OF FACILITY
b FEE SCHEDULE NEGOTIABLE DEPENDING ON INTERESTS OF INSTITUTION

TABLE C4 (CONTINUED)

AVAILABILITY OF JAPANESE FACILITIES FOR U.S. USE

INSTITUTION	AVAIL. FOR U.S. GOV'T. AGENCY, CONDITIONS FOR USE	AVAIL. FOR U.S. PRIVATE FIRMS, CONDITIONS FOR USE	U.S. ORGANIZATIONS HAVING USED OR CONSIDERING USE	FACILITY USE		TYPES OF STRUCTURES TESTED
				RESEARCH	NON-RES.	
PHRI	AVAILABLE (1,FREE)	AVAILABLE (6,1,b)	NONE	70 %	30 %	PORT, HARBOR
PWRI	AVAILABLE (4,a)	AVAILABLE (6,4,a)	UNIVERSITIES,UJNR	80 %	20 %	BRIDGE, TUNN
SHIMIZU	AVAILABLE (5,b)	AVAILABLE (5,b)	NONE	50 %	50%	BUILDINGS NUC.POW.PL.
TAISEI	AVAILABLE (4,a)	AVAILABLE (6,4,a)	PRIVATE FIRM	70 %	30%	BUILDINGS NUC.POW.PL.
NTT-TEDC	AVAILABLE (2,a)	AVAILABLE (2,a)	NONE	70 %	30 %	COMMUN.FAC.
OKUMURA	AVAILABLE (5,a)	AVAILABLE (5.a)	NONE	40 %	60 %	SOIL-STRUC
TODA	AVAILABLE (5,a)	AVAILABLE (5,a)	NONE	20 %	80 %	R/C BLDGS.
JNR	AVAILABLE (3,b)	AVAILABLE (3,b)	NONE	30 %	70 %	EARTHWORKS BRIDGES
IIS	AVAILABLE (1,a)	AVAILABLE (6,4,a)	UNIVERSITIES	80 %	20 %	BUILDINGS, INDUSTRIAL

AVAILABILITY CODES:

1	MAXIMUM OF 1 MONTH ON ANY PROJECT
2	MAXIMUM OF 2 MONTHS USE ON ANY PROJECT
3	MAXIMUM OF 3 MONTHS USE ON ANY PROJECT
4	TIME SCHEDULE NEGOTIABLE
5	TIME SCHEDULE ADJUSTABLE, DEPENDING ON INTERESTS OF INSTITUTION
6	FACILITY AVAILABLE TO PRIVATE FIRMS ONLY FOR JOINT RESEARCH
a	FIXED FEE SCHEDULE FOR USE OF FACILITY
b	FEE SCHEDULE NEGOTIABLE DEPENDING ON INTERESTS OF INSTITUTION

APPENDIX D

N.E.E.E.F. WORKSHOP
GAITHERSBURG, MARYLAND
NOVEMBER 18-19, 1986

An important objective of the first phase of the study was to obtain input from as wide a segment of professional and trade organizations and government agencies as possible. In order to accomplish this objective, a workshop was held in Gaithersburg, Maryland on November 18-19, 1986 to allow all interested groups to hear the recommendations of the six consultants and to offer additional suggestions for needed research.

The six consultants who had been hired to study experimental needs in the six specific areas of interest (low-rise, medium-rise, and high-rise structures, industrial process facilities, power facilities, and lifelines) prepared technical reports (Ref. 5-10) discussing experimental needs and presented their recommendations on the morning of the first day of the workshop. Participants in the workshop were then divided into six working groups to discuss, modify, and add to these recommendations. At the conclusion of the workshop, each of the six working groups reported the results of their discussions.

In arriving at the testing needs identified in Table 1 in the body of this report, a large number of tests were considered in each category. In general, each consultant attempted to identify all tests which might be desirable in the assigned category. As an example, the consultant responsible for determining the testing needs for medium-rise buildings developed a total of twenty-four specific tests needed which ranged from consideration of torsional response of irregular buildings to quantifying the benefits of redundancy in a structure during seismic action. The seven tests recommended finally for medium-rise buildings in Appendix E were those determined by the consultant and the working group at the workshop to be those most important among all tests considered. A similar procedure was used to identify the most important testing needs for the other categories of structures.

The following individuals participated in the workshop and represented the organizations shown:

Dr. Ahmed M. Abdel-Ghaffar
Dynamics Committee of the Engineering Mechanics Division
American Society of Civil Engineers

Dr. Daniel P. Abrams
The Masonry Society

Dr. Satish Abrol
Headquarters, USAF

Dr. James Beavers
National Research Council

Dr. John J. Burns
U.S. Nuclear Regulatory Commission

Dr. Manmohan S. Chawla
General Services Administration

Dr. Riley M. Chung
National Research Council

Mr. John Coil
Structural Engineers Association of California

Mr. James Cooper
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Steel Plate Fabricators Association

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Dr. Joseph Reynen
Commission of the European Communities

Dr. Henry G. Russell
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American Insurance Services, Inc.

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The following organizations were also given the opportunity to review the recommendations developed at the workshop and to offer further needs for experimentation:

American Assoc. of State Highway and Trans. Officials
American Concrete Institute
American Consulting Engineers Council
American Institute of Timber Construction
American Plywood Association
American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.
American Society of Mechanical Engineers
American Society for Testing and Materials
Applied Technology Council
Associated General Contractors of America
Association of Major City Building Officials
Brick Institute of America
Building Officials and Code Administrators, International
Building Seismic Safety Council
Concrete Masonry Association of California and Nevada
Concrete Reinforcing Steel Institute
Council on Tall Buildings
Earthquake Engineering Research Institute
Electric Power Research Institute
International Conference of Building Officials
Metal Building Manufacturers Association
National Association of Home Builders
National Concrete Masonry Association
National Conference of States on Building Codes and Standards
National Electrical Manufacturers Association
National Forest Products Association
National Ready-Mixed Concrete Association
Nuclear Regulatory Commission
Post-Tensioning Institute
Prestressed Concrete Institute
Rack Manufacturers Institute
Southern Building Code Congress International
Steel Deck Institute, Inc.
Structural Engineers Association of Arizona
Structural Engineers Association of Utah
United States Forest Products Laboratory
University Council on Earthquake Engineering Research
Western States Council Structural Engineers Association
Western States Clay Products Association

APPENDIX E
RECOMMENDATIONS FOR LARGE-SCALE TESTING

For the purposes of this report, needs for large-scale seismic testing were considered for low-rise, medium-rise, and high-rise buildings, industrial processing facilities, power facilities, and lifelines. Recommendations were developed for all areas except lifelines. The recommendations for research in the area of lifelines were concerned primarily with bridges. These research needs and recommendations for the facilities required to conduct this research have not been presented here for two reasons. First, these recommendations were similar in nature to those presented previously in a report on research needs for bridges (see Appendix A, Workshop 3). Second, many of the tests recommended can be done more appropriately as in-situ tests on actual structures rather than in a central laboratory. These tests, although important to a total program of seismic testing, are not of interest to this study of a national facility.

The following sections summarize the needs for research and recommendations for testing identified as being appropriate to a national experimental facility. The recommended tests in each section are listed in priority order.

A. LOW-RISE STRUCTURES

For the purposes of this report, low-rise buildings were defined as those structures less than four stories high. Such buildings can be tested under static lateral loads using a large reaction wall. In addition, many low-rise structures, such as wood-frame residential buildings, are small enough to fit on a large shaking table. Low-rise structures often consist of an assemblage of several similar or identical modules, one of which also might be small enough to fit on a large shaking table.

RECOMMENDATION A1: TILT-UP CONSTRUCTION

TESTS ARE NEEDED TO DETERMINE THE BEHAVIOR OF TILT-UP CONSTRUCTION HAVING PANALIZED PLYWOOD ROOF DIAPHRAGMS

A full scale test of a single-story tilt-up industrial building is needed to study the behavior and response of this type of structure, particularly of a panalized plywood roof diaphragm, the interaction of walls and roofs, and the response of connections between the roof and walls.

Facility requirements for this test:
Shaking Table:
Size: 9 m x 18 m
Weight Capacity: 1330 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 4 man-years

Note: Additional review of this type of structure has indicated that there may be some difficulties in developing a test model that will accurately simulate actual conditions. In lieu of a shaking table test, individual actuators may have to be used. Additional study will be required to develop more accurately the test facility requirements.

RECOMMENDATION A2: WOOD-FRAME RESIDENTIAL HOUSING

TESTS ARE NEEDED TO DETERMINE THE PERFORMANCE OF A TWO-STORY WOOD-FRAME RESIDENTIAL BUILDING

Tests of a two-story wood-frame residential structure would be designed to determine overall response of this class of structure, deformation patterns of walls and roofs, interaction between components of the structure, and behavior of connections, non-structural partitions, and foundation anchorages.

Facility Requirements for This Test:
Shaking Table:
Size: 8 m x 12 m
Weight Capacity: 180 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 3 man-years

RECOMMENDATION A3: SPLIT-LEVEL RESIDENTIAL STRUCTURE

TESTS ARE NEEDED TO DETERMINE THE PERFORMANCE OF SPLIT-LEVEL RESIDENTIAL STRUCTURES

The test of a two-story split-level residential structure having a large garage door opening would provide information about the interaction between sections of the structure and the effects of the garage door opening on the performance of the structure. This configuration of test specimen would also be used to investigate the methods of tying together sections of residential structures.

Facility Requirements for This Test:
Shaking Table:
Size: 12 m x 12 m
Weight Capacity: 270 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 3 man-years

RECOMMENDATION A4: CAVITY-WALL MASONRY STRUCTURE

DYNAMIC TESTS OF MASONRY STRUCTURES SUBJECT TO MODERATE EARTHQUAKES ARE NEEDED

A large number of commercial structures in the eastern U.S. and in other regions of the country in which seismic risk is low are of cavity wall masonry construction, in which two wythes of masonry units are separated by an air space and held together with metal ties. The test of such a structure under moderate seismic forces (maximum lateral accelerations of 0.2 g.) would help to determine its resistance to lateral loads and would serve as a proof test of this common type of construction.

Facility Requirements for This Test:
Shaking Table:
Size: 8 m x 12 m
Weight Capacity: 800 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 6 man-years

RECOMMENDATION A5: LIGHT-WEIGHT STEEL STRUCTURES

DYNAMIC TESTS OF A THREE-STORY OFFICE BUILDING ARE NEEDED TO DETERMINE THE SEISMIC RESISTANCE OF LIGHT-WEIGHT METAL MOMENT FRAMES

A common form of construction for small office buildings consists of lightweight steel moment frames formed by tubular columns and open web joists. Tests of a three-bay by three-bay structure of this type are needed to determine the performance of this popular type of construction during earthquakes. Although a typical prototype structure would be approximately 30 m square in plan, it is believed that a 2/3 scale model would accurately demonstrate the performance of the structure.

Facility Requirements for This Test:
Shaking Table:
Size: 18 m x 18 m
Weight Capacity: 3600 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 5 man-years

RECOMMENDATION A6: MOBILE HOME ANCHORAGE

DYNAMIC TESTS ARE NEEDED TO CERTIFY SYSTEMS FOR ANCHORING MOBILE HOMES

Mobile homes are manufactured in sizes as large as 4.3 m by 22 m for single-width homes and 8.6 by 15 m for double-width homes. One of the critical aspects of the performance of these manufactured homes is the system used to anchor the structure to either the soil or to a prepared foundation. A shaking table could be used to test and certify the various systems designed to anchor these homes against both wind and earthquake loads.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 18 m
Weight Capacity: 180 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0.2 - 20 Hz.
Estimated level of effort for this project: 2 man-years

B. MEDIUM-RISE STRUCTURES

For purposes of this report, medium-rise structures were considered to be those between four and fifteen stories in height. Medium-rise structures make up a majority of commercial construction. Full-scale medium-rise concrete and steel frame structures have been tested using a very large reaction wall in Tsukuba, Japan, and a full-scale medium-rise masonry structure is currently being prepared for testing. The following research needs and tests necessary to satisfy those needs have been identified:

RECOMMENDATION B1: CONCRETE FRAME STRUCTURES

TESTS OF FULL-SCALE MOMENT FRAME AND DUCTILE MOMENT FRAME STRUCTURES ARE NEEDED TO DETERMINE THE BEHAVIOR OF THESE STRUCTURAL SYSTEMS UNDER LATERAL LOADING

Full-scale static lateral load tests of a medium-rise concrete frame structure have been conducted in Japan. However, the details of reinforcement used in that structure were not the same as those used in similar structures in the U.S. Tests of concrete frame structures containing reinforcement detailed in accordance with U.S. practice are needed. A test of a ductile moment frame structure would address the needs of designers of structures built in zones of severe seismic risk. The test of an ordinary moment frame structure would examine the behavior of concrete frame structures built in regions of low seismic risk.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 12,900 kN
Maximum Acceleration: 0.8 g., X,Y directions
Frequency Range: 0 - 30 Hz.

Reaction Wall:
Test Bed Dimensions: 18 m x 18 m
Reaction Wall Height: 23 m
Wall Shear Capacity: 5.60 MN
Wall Moment Capacity: 82 MN-m
Estimated level of effort for this project: 6 man-years

RECOMMENDATION B2: STEEL MONEMT FRAME STRUCTURE

TESTS OF A STEEL MOMENT FRAME STRUCTURE CARRYING FULL DEAD LOAD AND LATERAL LOADS APPLIED IN ORTHOGONAL DIRECTIONS ARE NEEDED

A full-scale steel braced frame structure has been tested in Japan. This test did not address the behavior of steel moment frame structures, which make up a large percentage of steel frame structures in seismic regions of the U.S. A test of a 7-story steel moment frame structure carrying full dead load and lateral load applied in orthogonal directions is needed to define the behavior of this important type of structure.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 10,000 kN
Maximum Acceleration: 0.8 g., X,Y directions
Frequency Range: 0 - 30 Hz.

Reaction Wall:
Test Bed Size: 18 m x 18 m
Reaction Wall Height: 27 m
Wall Shear Capacity: 5.60 MN
Wall Moment Capacity: 82 MN-m

Estimated level of effort for this project: 6 man-years

RECOMMENDATION B3: MEDIUM-RISE STRUCTURES WITH BASE ISOLATION

TESTS OF A MEDIUM RISE STRUCTURE INCORPORATING A SYSTEM OF BASE ISOLATION DEVICES IS NEEDED

The use of base isolation devices to reduce earthquake damage is receiving considerable attention. Controlled tests of full-scale structures incorporating such devices are needed to provide performance data on their functioning and effect on structural response.

Facility Requirements for This Test:

Same as for Recommendation B1.

Estimated level of effort for this project: 3 man-years

RECOMMENDATION B4: DYNAMIC TEST OF BUILDING WITH SOFT STORY

TESTS OF A STEEL FRAME STRUCTURE HAVING A SOFT STORY ARE NEEDED

As a result of commercial use, the first story of many medium-rise structures is quite flexible (soft story). Test data are needed for such structures. This test can be conducted in conjunction with the test of the steel moment frame structure recommended above.

Facility Requirements for This Test:
Same as for Recommendation B2.

Estimated level of effort for this project: 3 man-years
(to be done in conjunction with other projects)

RECOMMENDATION B5: FULL-SCALE TESTS OF NON-STRUCTURAL COMPONENTS

TESTS ARE NEEDED TO DETERMINE THE BEHAVIOR OF NON-STRUCTURAL COMPONENTS COMMON IN STEEL MOMENT FRAME STRUCTURES

Non-structural components of structures subjected to earthquakes present a serious problem for designers and represent one of the greatest expenses associated with damage from earthquakes, even if the structure remains relatively intact. Tests are needed to determine the contribution of various types of curtain walls and other non-structural components to the stiffness and strength of frame structures and to determine the behavior of anchorage systems used to connect non-structural and structural elements. These tests could be most efficiently done in connection with the test of the steel frame structure recommended above.

Facility Requirements for This Test:
Same as for Recommendation B2.

Estimated level of effort for this project: 2 man-years

RECOMMENDATION B6: PRECAST COMPONENTS

TESTS ARE NEEDED TO DETERMINE THE BEHAVIOR OF STRUCTURES CONSTRUCTED FROM PRECAST COMPONENTS

It is recommended that a seven-story reinforced masonry bearing wall structure having precast components be tested. This structure should contain precast floors, both with and without topping, in addition to other selected precast components.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 7,100 kN
Maximum Acceleration: 0.8 g., X,Y directions
Frequency Range: 0 - 30 Hz.

Reaction Wall:
Test Bed Size: 18 m x 18 m
Reaction Wall Height: 23 m
Wall Shear Capacity: 8.9 MN
Wall Moment Capacity: 136 MN-m
Estimated level of effort for this project: 6 man-years

RECOMMENDATION B7: STEEL STUDS AND GYPSUM BOARD SHEATHING

TESTS ARE NEEDED TO DETERMINE THE BEHAVIOR OF WALLS CONSTRUCTED OF LIGHT-GAGE STEEL STUDS AND GYPSUM BOARD SHEATHING

A five- or six-story structure would be used as a vehicle to examine the behavior of walls constructed of light-gage steel studs and gypsum boards. Walls of this type are common in light office construction, but their contribution to the stiffness and strength of the structure is unknown.

Facility Requirements for This Test:

Same as for Recommendation B2.

Estimated level of effort for this project: 4 man-years

C. HIGH-RISE STRUCTURES

High-rise structures, defined here as those structures taller than fifteen stories, present a unique set of problems, not only for designers, but for those contemplating full-scale or large-scale tests of representative structures. Even the largest feasible shaking tables or reaction walls are not large enough to test a complete high-rise structure at a large scale. In addition, a test of a large-scale three-dimensional model of a high-rise structure could be prohibitively expensive.

It will probably never be possible to test a complete, full-scale, high-rise structure in any laboratory. The types of tests recommended for determining behavior of high-rise structures may be divided into either quarter-scale tests of complete structures or full-scale tests of structural components. The specific research recommendations which have been identified include the following:

RECOMMENDATION C1: FRAMED TUBE SUBASSEMBLY

FULL-SCALE TESTS OF COMPONENTS OF A FRAMED TUBE ARE NEEDED TO DEFINE BEHAVIOR OF THAT TYPE OF STRUCTURE

A full-scale test of a subassembly of a framed tube structure is needed to study behavior of such a system having strong beams and relatively weaker columns. This test would determine the effects of localized yielding on redistribution of forces within the system, the ability of the system to maintain its load-carrying capacity, and P-delta effects. Quarter-scale tests are proposed.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 4,450 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0 - 15 Hz.
Estimated level of effort for this project: 4 man-years

RECOMMENDATION C2: ENERGY-DISSIPATING DEVICES

TESTING OF ENERGY DISSIPATING DEVICES ARE NEEDED TO DETERMINE THE EFFECTS OF THOSE DEVICES ON STRUCTURAL RESPONSE

Energy dissipating devices can be installed throughout a high-rise structure, but their effect on performance has never been experimentally verified. The ability to conduct full-scale tests would stimulate development of the components and confidence in their performance.

Facility Requirements for This Test:
Same as for Recommendation C1.

Estimated level of effort for this project: 2 man-years

RECOMMENDATION C3: DUAL SYSTEMS

TESTS ARE NEEDED TO VERIFY THE DISTRIBUTION OF LOADS BETWEEN COMPONENTS OF DUAL STRUCTURAL SYSTEMS

Full- or large-scale tests of subassemblies of structures having dual systems designed to carry lateral loads. Tests are needed to determine the manner in which lateral loads are carried by the components of the system up to failure.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 4,450 kN
Maximum Acceleration: 0.6 g., X,Y directions
Frequency Range: 0 - 15 Hz.
Estimated level of effort for this project: 6 man-years

D. INDUSTRIAL PROCESSING FACILITIES

Industrial processing facilities include a wide variety of structures, equipment, and mechanical components such as large tanks, pressure vessels, piping, furnaces, and stacks. Many existing facilities were designed without consideration of earthquake loading and at a time when little was known about the characteristics of earthquake loads or the appropriate means of resisting these loads. The following summarize the recommendations for tests requiring a large national facility:

RECOMMENDATION D1: UNANCHORED TANKS

DYNAMIC TESTS OF UNANCHORED LIQUID-FILLED TANKS ARE NEEDED

Shaking table tests of unanchored tanks are needed to determine behavior of liquid filled tanks having floating roofs, open roofs, or closed roofs. These tests would be designed to study the effects of motions of the liquid within the tanks on buckling and failure of the tank walls and to study the behavior of piping connections to the tank.

Facility Requirements for This Test:
Shaking Table:
Size: 15 m x 15 m
Weight Capacity: 14,200 kN
Maximum Acceleration: 1.0 g. X, 1.0 g. Y, 0.5 g. Z
Maximum Displacements: 250 mm horizontal, 25 mm vertical
Maximum Velocity: 760 mm/sec.
Frequency Range: 0 - 10 Hz.
Estimated level of effort for this project: 6 man-years

RECOMMENDATION D2: RETROFIT MEASURES

TESTS OF RETROFIT METHODS FOR EXISTING INDUSTRIAL PLANTS ARE NEEDED TO DETERMINE PERFORMANCE OF THOSE METHODS OF STRENGTHENING

The vast majority of existing industrial plants were constructed either without consideration of or with crude consideration of seismic response of the plants. Full-scale tests would be designed not only to determine the behavior of existing plants, but also the effectiveness of proposed methods of retrofit.

Facility Requirements for This Test:

Shaking Table:
Size: 20 m x 20 m
Weight Capacity: 16,000 kN
Maximum Acceleration: 0.5 g., X,Y,Z directions
Maximum Displacement: 250 mm
Maximum Velocity: 760 mm/sec
Frequency Range: 0.1 - 30 Hz.

Reaction Wall:
18 m x 3 m test bed
L-shaped Reaction Wall Height: 12 m
Wall Shear Capacity: 2.2 MN
Wall Moment Capacity: 20.3 MN-m

Estimated level of effort for this project: 6 man-years

RECOMMENDATION D3: CHEMICAL AND REFINERY EQUIPMENT

TESTS OF REFINERY AND CHEMICAL PLANT COMPONENTS ARE NEEDED TO DETERMINE BEHAVIOR OF SELECTED COMPONENTS

Tests of several types of large components of chemical plants and refineries are needed. These components include the following:

Spherical and cylindrical pressure vessels
Piping systems
Cracking towers with piping
Stacks and chimneys

Facility requirements for these tests would be the same as those for unanchored tanks discussed above. An added condition of the test facility would be that 100 ft overhead clearance would be required for the shaking table to accommodate the stacks and cracking towers at an acceptable scale.
Estimated level of effort for this project: 7 man-years

E. POWER FACILITIES

Because of the many critical large electrical and mechanical components present in a typical power-generating or power transmission facility, the tests which are most needed by this industry are those which could determine the behavior of these major structural and mechanical components. The recommendations for testing are the following:

RECOMMENDATION E1: PLANT COMPONENTS

TESTS ARE NEEDED TO DETERMINE THE RESPONSE OF CRITICAL COMPONENTS OF POWER-GENERATING FACILITIES TO SEISMIC LOADING

A large number of the mechanical components of power-generating facilities are unique to those facilities. Tests of either full-scale components or of models are needed for two reasons. First, scale model tests of some components on a shaking table could increase understanding of the behavior of these components and help their designers to make them more efficient and safer from a structural standpoint. Second, full-scale tests of some critical components are needed as proof tests. The components to be tested, either at full scale or at reduced scale could include diesel generators, gas turbines, suspended boilers, coal handling systems, large-diameter high temperature ducts, and large suspended ceilings typical of those used in control rooms.

Facility Requirements for These Tests:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 4,450 kN
Maximum Acceleration: 0.5 g., X,Y,Z directions
Maximum Displacement: 250 mm
Maximum Velocity: 760 mm/sec
Frequency Range: 0.1 - 30 Hz.
Estimated level of effort for this project: 5 man-years

RECOMMENDATION E2: DISTRIBUTION SYSTEMS

FULL-SCALE TESTS OF COMPONENTS OF ELECTRICAL DISTRIBUTION SYSTEMS ARE NEEDED AS QUALIFICATION TESTS

Several failures of equipment at electrical distribution substations have highlighted the need for qualification tests of full-scale production components. The components should include large transformers, large switchgear, and other critical elements of power distribution systems.

Facility Requirements for This Test:
Shaking Table:
Size: 9 m x 9 m
Weight Capacity: 4,450 kN
Maximum Acceleration: 0.5 g., X,Y,Z directions
Maximum Displacement: 250 mm
Maximum Velocity: 760 mm/sec
Frequency Range: 0.1 - 30 Hz.
Estimated level of effort for this project: 4 man-years

RECOMMENDATION E3: SOIL-STRUCTURE INTERACTION

LARGE-SCALE TESTS ARE NEEDED TO DETERMINE EFFECTS OF SOIL-STRUCTURE INTERACTION ON SEISMIC RESPONSE OF STRUCTURES

The inability to successfully scale soil particle sizes leads to a need to perform large-scale tests of effects of soil-structure interaction on seismic response of powerplant structures. A large shaking table would be required to conduct coupled soil-structure tests with controlled input motions and realistic dimensions and boundary conditions. Such tests could include consideration of rigid concrete structures on raft or pile foundations, flexible steel structures on spread footings or piles, and the response of buried tanks, tunnels, shafts, and piping.

Facility Requirements for This Test:
  Shaking Table:
  Size: 15 m x 15 m
  Weight Capacity: 13,300 kN
  Maximum Acceleration: 0.5 g., X,Y,Z directions
  Maximum Displacement: 250 mm
  Maximum Velocity: 760 mm/sec
  Frequency Range: 0.1 - 30 Hz.
Estimated level of effort for this project: 6 man-years

RECOMMENDATION E4: TRANSMISSION TOWERS

TESTS ARE NEEDED TO DEFINE THE RESPONSE OF TRANSMISSION TOWERS TO SEISMIC LOADING

Because the overturning stability of some configurations of transmission towers is related to the absolute displacement of the ground during seismic loading, a large-scale test of such towers is needed to properly represent their potential to overturn. Tests for both truss-type and pole-type towers are recommended.

Facility Requirements for This Test:
  Shaking Table:
  Size: 9 m x 9 m
  Weight Capacity: 2,200 kN
  Maximum Acceleration: 0.5 g., X,Y,Z directions
  Maximum Displacement: 250 mm
  Maximum Velocity: 760 mm/sec
  Frequency Range: 0.1 - 30 Hz.
Estimated level of effort for this project: 2 man-years

APPENDIX F

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Mr. LYONS. My long written statement discusses in some detail our relations with other countries and our international activities, that will of course be in the record, according to Mr. Walgren's instructions. Finally, there is a discussion there of dissemination of research results of the various techniques we are using with our colleagues on this panel for disseminating our findings.

I will be glad to answer any questions you may have.

[The prepared statement of Dr. Lyons follows:]

U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899
STATEMENT OF
JOHN W. LYONS, DIRECTOR
NATIONAL ENGINEERING LABORATORY
NATIONAL BUREAU OF STANDARDS

BEFORE THE

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
ON THE
EARTHQUAKE HAZARD REDUCTION ACTIVITIES
OF THE
NATIONAL ENGINEERING LABORATORY
NATIONAL BUREAU OF STANDARDS

March 10, 1987

Mr. Chairman and Members of the Subcommittee: It is a pleasure for me to testify this morning on behalf of the National Bureau of Standards (NBS) to discuss the earthquake hazard reduction efforts at the NBS. These activities are conducted primarily by the Center for Building Technology and are an integral part of the NBS building research program. I am accompanied by Richard N. Wright, Director of the Center for Building Technology.

The National Earthquake Hazards Reduction Program (NEHRP) which resulted from the Earthquake Hazards Reduction Act of 1977 (P.L. 95-124) assigned NBS the following continuing responsibilities

- Provide technical support to the building community, including the federal agencies involved in construction, "in continuing the development, testing, and improvement of model seismic design and construction provisions suitable for incorporation in local codes, standards (including federal standards), and practices."
- Perform "research on performance criteria and supporting measurement technology for earthquake resistant construction."

NBS has worked closely with Federal Emergency Management Agency (FEMA) in its lead agency responsibility for coordinating the national earthquake program. NBS worked with FEMA in establishing and supporting the Federal Interagency Committee on Seismic Safety in Construction (ICSSC) and in participating in the non-Federal Building Seismic Safety Council (BSSC) activities. These efforts have led to development of considerable resource material for improving seismic design provisions for building codes and standards and practices for both private and Federal construction.

The ICSSC assists Federal departments and agencies involved in construction to develop earthquake hazard reduction measures for incorporation in their ongoing programs. The ICSSC, chaired by the NBS, currently is examining a number of problems of importance to the Federal Government, including standards for new buildings, assessment and strengthening of existing buildings, protection of lifelines, and response of the ICSSC to damaging earthquakes. The NBS is providing technical support for these activities. NBS chairs the ICSSC Subcommittee on Building Standards. This subcommittee developed seismic design guidelines for Federal buildings. The guidelines were approved by ICSSC as recommended practice and published in February 1987. These guidelines are intended for consideration and use, as appropriate, by Federal agencies for the planning design and construction of buildings. A copy of the report entitled Seismic Design Guidelines for Federal Buildings, NBSIR 87-3524 containing the guidelines and a commentary is provided for the record with my testimony.

The ICSSC has successfully balloted a proposed Executive Order "Seismic Safety of Federal and Federally Assisted or Regulated Construction." The order defines what Federal agencies must do to meet the requirements of the National Earthquake Hazards Reduction Act of 1977. It has been submitted by FEMA for processing by the Office of Management and Budget.

At the request of FEMA, the NBS has provided technical support to the Building Seismic Safety Council's (BSSC) program on improving seismic design provisions for building standards and codes. The seismic provisions considered in this program were originally prepared by the Applied Technology Council in 1978 in a major project sponsored by the National Science Foundation and the NBS. The seismic design procedures developed by BSSC through a consensus approval process of the Council membership were published in November 1985. The three-volume document, NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings has been printed by FEMA and made widely available. An update effort is now underway and due for completion in 1988. NBS is continuing to work with the BSSC in this effort through participation in the Technical committees developing the provisions and the oversight committee directing the project.

Existing hazardous buildings are in most cases the greatest source of danger to the population during a severe earthquake. We need to develop techniques to identify the most hazardous buildings. This work will include nondestructive test methods to determine the properties of buildings and their components in place, and various techniques for strengthening and repair. In Fiscal Year 1986, FEMA developed a comprehensive program plan to address this problem. NBS provided technical support to FEMA in this effort.

Subcommittee 1 of the ICSSC has begun work on developing procedures for identifying hazardous buildings. The procedures developed for use by Federal agencies are being coordinated with related efforts being conducted by BSSC for private sector buildings. NBS chairs the Subcommittee 1 effort and is providing technical support to the BSSC work. Roads, bridges, power distribution facilities and other lifeline structures are critically important in the post earthquake period. NBS is providing technical support to the FEMA effort to develop a program plan for addressing problems with lifelines. We will continue our participation in the program as it develops over the next several years.

NBS RESEARCH ACTIVITIES

The NBS laboratory research program is designed to provide information on which to base advanced structural design criteria for improving seismic behavior of new or existing building structures. The work is aimed to meet the most urgent research needs to fill the gaps in building codes and standards, to develop new criteria, and to make recommendations for repair and retrofit of existing structures. The research is conducted in cooperation with other Government agencies, practicing engineers and architects, professional organizations, trade associations, building owners, product manufacturers, standards and regulatory organizations, and university researchers. In planning this work, close liaison is maintained with these individuals and organizations. These interactions assist in identifying and assigning priorities to research problems in earthquake engineering. They also ensure that NBS efforts are coordinated with other work.

Strength design of masonry walls to resist earthquakes has been identified as an area in which there is a serious deficiency of supporting research. The NBS/Building Seismic Safety Council and others have indicated that research is needed to substantiate and improve the current code provisions for determination of shear wall resistance to earthquakes.

Fiscal Year 1986 saw the completion of the first phase of an NBS research program begun in Fiscal Year 1984. The program is to define the shear capacity and behavior of masonry walls. The first phase was devoted to unreinforced, hollow concrete block walls. The parameters studied included vertical compressive stress, wall aspect ratio (wall length to height), block strength, mortar type, and external flexural reinforcement. A total of forty-nine wall panels were tested. The wall panels were subjected to in-plane displacements in combination with vertical compression stresses using the unique NBS Tri-directional Test Facility (TTF), a computer-based test system. The results of phase one will be incorporated into recommendations for the design of masonry wall elements and submitted to the Masonry Structures Standards Committee of the American Concrete Institute and American Society for Civil Engineers in 1987. In addition, the information will serve as benchmark data for Phase Two involving studies of reinforced masonry walls. The reinforced masonry specimens are currently being fabricated and will be tested at NBS this spring.

Experiments are also in progress at NBS to study the behavior of connections in braced multistory steel frames. The program was developed in cooperation with American Institute of Steel Construction's Task Group on Bracing for Heavy Construction.

Multistory steel frame buildings frequently use a diagonally braced core to provide stability and to resist both earthquake and wind forces. It is common in such bracing systems to use steel plates (gusset plates) to connect the diagonal braces to the beams and columns. The force distribution in these plates and the force transmitted to the connecting members is complex and influenced by many factors which have not been experimentally verified.

Portions of a diagonally braced multistory frame or subassemblage are now being tested at NBS in the Tri-directional Testing Facility. Test boundary conditions will model those in the prototype building as closely as possible. The test specimens are about three-quarters of the size of typical buildings members.

Large-scale testing is an important component of the NBS laboratory work. Current work on full-scale bridge columns will extend understanding of the performance of very large structures and will provide data that are not currently available. One large-scale column 5 ft. in diameter and 30 ft. high, reinforced with 25 1.7-inch diameter reinforcing bars has been tested. This was the first full-scale laboratory test of this size to be conducted in the United States. The column was subjected to cyclic lateral displacements up to 2-feet while supporting vertical load simulating the weight carried by the columns. A second column of similar size is being fabricated at NBS and will be tested this spring.

A companion series of six one-sixth scale structural models have been tested to determine if research on small specimens can be safely extrapolated to the large sizes actually being used in bridges and to the large deformations expected in a severe earthquake. This work is being supported by the NBS, NSF, Federal Highway Administration (FHWA), and the California Transportation Department. The results of the one-sixth scale model tests have been reviewed by the California Transportation Department.

NATIONAL EARTHQUAKE ENGINEERING EXPERIMENTAL FACILITY

In 1984 the National Research Council published the results of its six month study on "Earthquake Engineering Facilities and Instrumentation" requested by the Office of Science and Technology Policy (OSTP). One of the major recommendations of the report was that "The Federal government should undertake, on an accelerated basis, planning aimed at developing a major national earthquake engineering experimental/test facility. The goals of that facility should be to provide the data and understanding necessary for rapid improvement in the design and construction of seismic-resistant structures."

The first phase of a four-year feasibility study for a National Earthquake Engineering Experimental Facility was completed by NBS last month. The study initiated by FEMA at the request of the Science Advisor to the President was funded at NBS during the first year by FEMA and NSF. A report has been prepared setting forth a five-year research program for a national facility in which full-scale or large-scale structures or structural components would be subjected to static and dynamic lateral loads. Representatives from a broad spectrum of professional, industrial and trade organizations, the National Research Council and Federal agencies participated in developing the research program. The proposed research program will provide a basis for the remaining portions of the study. The Policy Coordination Group of the NEHRP will consider continuation of the study. Funding is not presently available. A copy of the report entitled National Earthquake Engineering Experimental Facility Study: Phase One-Large Scale Testing Needs, NBS Special Publication 729 is provided for the record with my testimony.

INTERNATIONAL ACTIVITIES

The U.S./Japan Panel on Wind and Seismic Effects provides for cooperative activities of 15 U.S. agencies and nine Japanese agencies and participating representatives of private sector organizations. NBS provides the U.S.-side chairman and secretariat. The Panel conducts an annual technical conference, alternating between the U.S. and Japan. The 1986 conference was hosted by the U.S. in Washington, D.C. to discuss recent research results. The results were presented in 21 U.S. papers and 20 Japanese papers. A one-week technical study tour of laboratories and construction projects followed the technical meeting. Five workshops are planned for the coming year. The Panel continues to plan for data exchange and cooperative investigation of earthquake mechanisms, ground motion, and structural performance in important Japanese and U.S. earthquakes.

Other international cooperative programs include:

- A cooperative program with the French national laboratory for building research (Centre Scientifique et Technique du Batiment), which includes an information exchange project on seismic repair and retrofit of existing buildings.
- Cooperative programs with Yugoslavia funded by the U.S. Government and administered by the Department of State dealing with seismic design criteria, masonry shear wall

resistance to seismic loading, bridge columns, and potential of soils to liquefy.

The International Council for Building Research, Studies and Documentation (CIB) facilitates international cooperation in research and improvement of building practices. Topics of structural safety, timber structures, actions on structures, wall structures and earthquake hazard reduction are particularly relevant to the U.S. earthquake hazard reduction program. NBS participates in these CIB programs as a CIB full member and through individual membership in working commissions and participation in CIB management. NBS also participates as a titular member and provides the U.S. Delegate to the International Union of Laboratories for Research and Testing of Materials and Structures (RILEM). RILEM has established a technical committee for international cooperation and development of test methods for seismic resistance of structures.

IMPLEMENTATION

The success of Federal programs for achieving earthquake hazards reduction can be measured in terms of the extent to which the results are used by various government agencies and private sector building owners and users and the extent to which the results are incorporated in new standards and improved design practices. The working relationships that NBS has established with groups throughout the building community provide channels for achieving this implementation. NBS building research staff participate actively in standards development in the private sector as well as at Federal, State, and local levels, with 44 different staff members involved with 175 distinct standardization activities. These implementation and coordination efforts have resulted in the adoption of research findings in practice. For example, procedures being used by the engineering profession as a common basis for comparing results obtained from the Standard Penetration Test, a geotechnical engineering site investigation test method, are based in part on NBS earthquake research. This research also led to changes in the ASTM standard for the SPT test and to a new ASTM standard involving energy measurement techniques. NBS test results provide the basis for recommendations by the National Concrete Masonry Association to ASTM for modifying the details of the masonry prism test procedure. The California Transportation Department is considering modifications to their existing design procedures for bridge columns which would incorporate energy absorption concepts as a result of the NBS tests on full-scale and one-sixth scale model columns. The seismic provisions developed by the Applied Technology Council in the NSF/NBS sponsored project were used in developing the seismic risk map in the ANSI A58.1-1982 Standard, Minimum Design Loads for Buildings and Other Structures. Portions of the NEHRP Recommended Provisions are being considered by Committee 318 of the American Concrete Institute in developing the 1989 version of their Building Code Requirements for Reinforced Concrete Structures.

We conduct workshops for other Federal agencies on our earthquake research results and we participate in workshops put on by other agencies. As an example we have presented papers at workshops conducted by the USGS in the central U.S. and elsewhere.

Dissemination of the observations from post-earthquake reconnaissance surveys is an important means for communicating information on building performance to the engineering profession. Efforts already are underway. NBS staff participated with engineers from Mexico City in a special session on the Mexican earthquake on October 22, 1985, at the American Society of Civil Engineers (ASCE) Annual Meeting in Detroit. The NBS presentation concentrated on the structural aspects of building performance, illustrated various types of building damage, and discussed causes of failure. NBS staff also presented results of computer studies of buildings damaged in the earthquake at a special ASCE conference held in Mexico City on September 19, 1986 one year after the earthquake. Information on the earthquake and on building performance collected by the NBS/USGS reconnaissance team has been compiled on a video tape. Over 275 copies of this video tape have been distributed to Federal agencies, disaster preparedness groups at the state and local level, building officials, universities and design professionals. NBS also worked with the research community to plan an agenda of needed research.

This concludes my formal statement. I would be pleased to answer any questions you may have.

JOHN W. LYONS

Date of Birth: November 5, 1930

Birthplace: Reading, Massachusetts

Education: Degrees
Harvard University, A.B., Chemistry - 1952
Washington University, A.M., Physical Chemistry - 1963
Washington University, Ph.D., Physical Chemistry - 1964

Position:
Director
National Engineering Laboratory
National Bureau of Standards

As Director of the National Engineering Laboratory, Dr. Lyons is responsible for NBS's research in applied mathematics, building technology, electronics and electrical engineering, energy conservation, engineering standards development, fire, manufacturing engineering, and chemical engineering.

From April to December 1983, Lyons served as the Acting Deputy Director of the National Bureau of Standards.

As Director of the NBS Center for Fire Research until December 18, 1977, he was responsible for providing scientific and technical knowledge applicable to the prevention and control of fires.

Lyons served in various research and development positions at the Monsanto Company from 1955 to 1973. He specialized in the chemistry and uses of phosphorus-based chemicals including fire retardants. He served from 1971 to 1973 as a member of the ad hoc panel of fire research, a National Academy of Sciences evaluaton panel for the National Bureau of Standards.

He is author of three books: *Viscosity and Flow Measurements, The Chemistry and Uses of Fire Retardants,* and *Fire.* He was co-author and editor of Fire Research on Cellular Plastics. He has contributed chapters to five other books and has written numerous papers and articles on technical or research topics. His early research interest was the physical chemistry of polyeletrolyte solutions, especially formation of complexes with metal ions. This work emphasized the behavior of inorganic polyphosphates and desoxy ribonucleic acid (DNA).

Lyons is a member of the National Academy of Engineering, a Fellow of the American Association for the Advancement of Science, a Fellow of the Washington Academy of Science, a member of the Naval Research Laboratory Naval Research Advisory Committee, a member of the Office of Science and Technology Policy Committee on Federal Laboratories, member of the American Chemical Society (past chairman of the St. Louis Section) and member of Sigma Xi. He serves on the Advisory Committee for Engineering, National Science Foundation; Advisory Council, College of Engineering, University of Maryland; Board of Directors, National Fire Protection Association and Board of Directors, American Society for Testing and Materials. He served on a special committee of the Maryland State Board for Higher Education to study the needs for engineering education (1983-84). He was chairman of the Products Research Committee (1974-79), a nine-member charitable trust administering a $5M research fund on fire research; co-chairman of the US-Japan Natural Resources Panel of Fire Research (1975-78). He received the Presidential Management Improvement Award in 1977 and the US Department of Commerce Gold Medal, also in 1977. In 1981 he received the Presidential Rank Award of Distinguished Executive. He received the Edward Uhler Condon Award in 1986 for the book *Fire.*

RICHARD N. WRIGHT

Date of Birth: May 17, 1932

Birthplace: Syracuse, New York

Education:

B.S., Civil Engineering, 1953
Syracuse University
M.S., Civil Engineering, 1955
Syracuse University
Ph.D., Civil Engineering, 1962
University of Illinois

Position:

Director, Center for Building Technology
National Engineering Laboratory
National Bureau of Standards

His professional experience includes: junior engineer with the Pennsylvania Railroad, 1953 to 1955: Instructor, assistant professor, associate professor and professor of civil engineering at the University of Illinois at Urbana from 1957 to 1974; and at the National Bureau of Standards, Chief of the Structures Section, Building Research Division 1971 to 1972, Deputy Director-Technical, Center for Building Technology, 1972 to 1973, and Director, Center for Building Technology 1974 to present.

The Center for Building Technology (CBT) is the national building research laboratory. It conducts laboratory, field and analytical research. It develops technologies to predict, measure and test the performance of building materials, components, systems and practices. It works cooperatively with other organizations, private and public, to improve building practices. CBT does not promulgate or enforce building standards or regulations, but its results are widely used in the building industry and adopted by private and governmental organizations that have standards and codes responsibilities. CBT programs include: computer integrated construction, structural safety, earthquake hazards reduction, building environment, quality of building materials, and cement hydration.

CBT has unique laboratory facilities and a staff of engineers and scientists of international reputation. Principal disciplines are structural, geotechnical, materials, mechanical and electrical engineering, physics, chemistry, architecture and behavioral sciences. Of the 100 professional staff members, 50 have earned doctoral degrees and 30 are registered engineers or architects. About 50 research associates sponsored by industry, visiting scholars from universities, and guest workers from foreign laboratories complement the professional staff.

Dr. Wright has published over 50 articles on computer aided design, formulation and expression of design criteria, performance criteria for buildings, structural design methods for earthquakes and other dynamic loads, flow and fracture in structural metals and mechanics of thin-walled beam structures.

He is President of the Liaison Committee of International Civil Engineering Organizations, Past President and Programme Committee Chairman of the International Council for Building Research, Studies and Documentation, Chairman of the Interagency Committee on Seismic Safety in Construction, U.S. Chairman of the U.S.-Japan Panel on Wind and Seismic Effects, fellow of the American Society of Civil Engineers, and member of the International Union of Testing and Research Laboratories for Materials and Structures, Earthquake Engineering Research Institute, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi. He registered as a professional engineer in New York in 1958 and as a structural engineer in Illinois in 1974.

He received the Gold Medal Award of the Department of Commerce in 1982 for distinguished achievement in the Federal Service, and the Special Presidential Award of the Illuminating Engineering Society of North America in 1983 for contributions to the organization of the Lighting Research Institute.

Mr. **Boehlert**. Fine. Thank you very much, Dr. Lyons.

I am going to ask this of all the panelists and go one by one to left to right, with Mr. McLoughlin starting out. Are any of your agencies proposing reprogramming a rescission for FY 1987 that would adversely affect the earthquake program?

Mr. **McLoughlin**. Mr. Chairman, not at the moment; no. We are not contemplating any.

Mr. **Boehlert**. Mr. Frederick?

Mr. **Frederick**. The Geological Survey does have a proposal for 1987 reprogramming to the Department of the Interior now for $1.5 million reduction. That would impact the development of a national seismic network.

Mr. **Boehlert**. $1.5, you say?

Mr. **Frederick**. $1.5 million, Mr. Chairman. That money is required to fund the USCS contribution to funding the new Civil Service Retirement System and the 3 percent pay raise for the civilian employees.

Mr. **Boehlert**. Dr. Suh?

Mr. **Suh**. NSF is not planning any reprogramming at this time.

Mr. **Boehlert**. How about Dr. Lyons?

Mr. **Lyons**. We have no plans for reprogramming or rescission.

Mr. **Boehlert**. What effect would that have on the program?

Mr. **Frederick**. In the fiscal year 1987 budget we were given $1.5 million by the Appropriations Committee designated for the development of a new national seismic network, in cooperation with NRC. The impact will be to defer our part, at least our funding, for that. We do intend to work with the Nuclear Regulatory Commission to develop prototype stations and begin the development of a seismic network for the eastern United States; specifically, this is the plan at the moment. And we have an MOU with the Nuclear Regulatory Commission and a promise of some funding, for fiscal year 1987 and a promise of additional funding to implement a new seismic network for the United States.

So the absence of that funding will slow that down a bit, but we still are——

Mr. **Boehlert**. But how long? Do you have a feel for that timetable?

Mr. **Frederick**. Let me ask John Filson who heads that program if he has a better feeling than I do about the delay.

Dr. **Filson**. We can proceed, as Mr. Frederick said, with the implementation of the network in the eastern United States. That should take place over about a five-year period. In the absence of additional funding for extending that network, we think we can do this very slowly, incrementally, following the five-year deployment effort in the eastern United States, in the next 6 to 10 years.

Mr. **Boehlert**. Another question for all the panelists. We're going to hear today from some of the witnesses who are going to argue that we should have a more centralized program with a leader that could set priorities for the entire program. How would you respond to that?

Mr. **McLoughlin**. Mr. Chairman, clearly there are differing ways to deal with the leadership role. The GAO study that took a look at FEMA's role as defined in the Act, acknowledged the fact that there are two possible ways to do this; one is as a coordinator, the other is as a manager of the program.

And in effect if we're talking about the coordination role, you're simply talking about the calling of meetings, the preparation of reports from all of the agencies, the submission of those, and trying to provide an environment in which the issues in earthquake can be discussed.

In a management role, in effect, you do need a strong actor at the center of it. And from our perspective, we think that there are some improvements that can be made, moving away from a coordinating role towards a more centralized approach in the earthquake program. Now, I recognize that is likely to be a fairly contentious sort of issue, but there does need to be some way to provide for a balance in the program.

Right now, the only place that the earthquake program as such is dealt with is before the authorization committees. Each of us have separate appropriation committees, each of us have different OMB examiners, each of us have different constituencies. So it is clear that only here is there a view of looking at this from an overall program perspective.

Mr. BOEHLERT. And we are all looking at it. [Laughter.]

Mr. Frederick?

Mr. FREDERICK. I guess from the point of view of the Geological Survey, we think the existing mechanism works very well. With the authorization bill and the oversight of this committee and the similar committee in the Senate, we think there is a great deal of oversight.

In addition to that, the agencies do talk on a continuing basis, and there is a great deal of interchange on program ideas as well as program structures.

There's another point that perhaps we ought to lay on the table. I think it was mentioned by Jim Hays a little bit earlier that there is a great deal of contribution into the Earthquake Program from many of the other related geosciences that we think also effectively play into this. But even though we have separate appropriation committees and somewhat separate programs, I think the present structure allows for a very effective program overall, and that the program is well balanced at this point.

Mr. BOEHLERT. How about you, Dr. Suh, would you have a comment on that?

Mr. SUH. Well, I think I concur with the previous witness. We believe that the current system works fairly well. But within the context of research, we believe that there has to be a balance between single investigator-initiated research projects and a large center program where we do more concentrated effort on certain items that have higher priorities. That is the reason we established the SUNY-Buffalo National Earthquake Engineering Research Center; the center can look at the earthquake research issues more from a systems point of view, and then generate the results that can be implemented on a more systematic basis.

There is a constant struggle between the research community and the people who are interested in implementation of the research results. Some claim that we have done enough research and therefore we don't need to do anymore, and all we've got to do is implement the research results that are available.

But that kind of discussion has been an ongoing discussion ever since people began to do intellectual work. Some people feel that there is enough knowledge existing at any given time. But history proves to us that the more research we do, the more we advance the state of knowledge. There's no question about that.

So in my opinion, this kind of research has to go on, and somebody has got to initiate it—this is done by the researchers because they are the ones who come up with ideas. But at the same time, on the national level we must look at the issues as a systems problem and see how we can resolve them. I think we are trying to strike this balance at the National Science Foundation.

Mr. BOEHLERT. Thank you. How about you, Dr. Lyons, do you have any comment on that?

Mr. LYONS. Yes, Mr. Chairman, I do. I have worked under a variety of different situations with respect to trying to coordinate multi-agency programs, and I remember very well when I was the Director of the Center for Fire Research we operated under a particular mechanism that this committee created in the Fire Prevention and Control Act of 1974, in which our budget was in the Fire Administration's budget and the program priorities were to be set in consultation with the Fire Administrator, in the event the committee undid that activity. Because it's very awkward for a part of an agency like NBS to work under guidance from some other agency; things just don't work that way.

So short of forming an agency for earthquake hazard mitigation, which I am not proposing, I don't think that you can do much better than what we are doing now. I would not want to centralized it anymore.

Mr. BOEHLERT. Thank you. Mr. McLoughlin, I've got one for you. How will state and local preparedness programs be affected in the western and eastern United States by the proposed cost-sharing?

Mr. MCLOUGHLIN. My guess is, Mr. Chairman, that it will be spotty. But certainly we are aware of strong support from state and local governments to continue the 100 percent funding effort.

Mr. BOEHLERT. To no one's surprise.

Mr. MCLOUGHLIN. To no one's surprise, that is correct. We have been in cost-sharing arrangements for a period of time with some of the states; the State of California since the early eighties has been cost-sharing the work that is being done out there in both the southern California and the San Francisco area.

Mr. BOEHLERT. Fifty-fifty basis?

Mr. MCLOUGHLIN. Recently it has been 50–50, yes. The California legislature has been putting in about $750,000 and we have been putting in about $750,000 into the two areas combined. So it has been 50–50 there.

There are other States where either States or localities have contributed. Now clearly, we know that there are some potential impacts that could occur in this area. There are some States conceivably that would drop out of the program.

Mr. BOEHLERT. Do you have any feel for which States might conceivably drop out? And the reason I ask that, I know it's happening and so do you—Federal revenue-sharing is no more. We in Washington are sending fewer dollars back home. Now we're asking back home, if you will, euphemistically, to share in the cost of this program and I'm just wondering where the resources are going to come from. Not that we have unlimited resources here. But I'm trying to get at the potential negative impact on the program. Which states have signaled you?

Mr. McLoughlin. I know that you are going to hear from some members in the second panel who will support the idea of continuation of 100 percent funding. I don't know that we have a strong indication of any particular States that might drop out. One of the problems always is that when the threat of going to cost-sharing arises, then there is clearly an attempt to maintain the status quo at 100 percent.

The important thing I think to recognize here is two-fold. One is not only that deficit reduction is one of the things that is driving this, but State and local governments do indeed have the primary responsibility for public health and safety. Cost sharing is one of the things that has to happen if we are going to institutionalize preparedness efforts at both the State and local level, certainly they need to make a contribution towards this in order to institutionalize it in their governments.

The last point that I would make is that we are talking about $500,000 roughly nationwide in terms of any reduction in the earthquake program, which is not a great deal of money.

Mr. Boehlert. The five-year plan envisioned substantially higher spending on NEHRP in 1988 than is being proposed. Do you still believe the numbers in the plan are valid, and why aren't they being adhered to? Let's go one by one if we can again. Mr. Frederick, we'll let you start on that one while Mr. McLoughlin is thinking a little bit about it.

Mr. Frederick. I guess you would have to say that in the present budget climate, we think the proposed program is reasonable. From an operational program and a scientific point of view, we think the figures in the five-year plan are reasonable in terms of the kinds of things that we could do, the sorts of things that we could accomplish and that sort of thing. So from that point of view, we think that's reasonable.

Mr. Boehlert. But we don't have reasonable figures in both instances, do we? The five-year plan and the present budget? How can they both be reasonable?

Mr. Frederick. Well, in light of the budget constraints, we think there are things that we must do, as Federal agencies, to meet the Gramm-Rudman-Hollings targets, and we have taken a close look at all of our programs and made adjustments accordingly. So in that context we——

Mr. Boehlert. Are you sacrificing any high priority item?

Mr. Frederick. Well, we aren't sacrificing the highest priority items, let me put it that way. There are things that we surely would like to do, and we think that would contribute. But again, considering the budget situation we think that we aren't giving up those things that we would consider an absolute have-to-do kind of a program.

Mr. Boehlert. So we are not putting the program at risk if we don't adhere to the five-year plan?

Mr. FREDERICK. Well, we don't think so for this cycle though. We think that year to year we have to look at the program and see what we've done and see if we need to change our minds about things and opportunities that occur.

Mr. BOEHLERT. Fine. Dr. Suh, would you care to comment on that, please?

Mr. SUH. Well, I guess the National Science Foundation is the exception in this case in the sense that first of all——

Mr. BOEHLERT. You're having a good year, aren't you? [Laughter.]

Mr. SUH. Well, I think the fact that the State of New York has so far put in several million dollars in general earthquake research together with the National Science Foundation is really substantially adding a great deal of impetus for the advances in this field. So in that sense, that's a positive move forward.

Furthermore, as you know, Mr. Chairman, the President is now asking that the NSF budget be doubled during the next five years. And with that increase in the NSF budget, I am sure that we will also be increasing research in this area as well. So I'm looking forward to having a greater contribution made by the research community.

Mr. BOEHLERT. Dr. Lyons.

Mr. LYONS. If I look in the five-year plan, Mr. Chairman, on page F-16 I see 0 for NBS, so I am happy to report to you that we will do better than that. [Laughter.]

And we think that in fiscal year 1988 we will be back higher than the level we were at in 1986. So from that point of view——

Mr. BOEHLERT. A move in the right direction for NBS.

Mr. LYONS. Moving in the right direction. But you know better than I the considerations with respect to CBT's budget for 1988.

Mr. BOEHLERT. And Mr. McLoughlin?

Mr. MCLOUGHLIN. Mr. Chairman, we believe that the numbers in there are acceptable given the environment that we are working in right now. I would add that we think it is important that we do indeed attend to the five-year plan and attend to the goals that are defined in the five-year plan, and direct the National Earthquake Protection dollar budget to the efforts and objectives that are clearly included in there.

And I might add one thing that Dr. Nam Suh mentioned a few minutes ago, because we do have some alternate view with respect to the proportion of the budget in the research area that does indeed go to the application as well as the basic research.

Clearly, we believe in a strong basic research program; you have to have the basic fundamental knowledge to do any kind of implementation and application. We come from a position in FEMA that the principal criterion by which we make judgments is in life safety; that's where the real payoff is in terms of the work that we're doing in earthquake. And we do support a larger proportion of the budget going to applied research, focused research on end products that can be used by the implementing community.

Mr. BOEHLERT. Thank you very much. Mr. Valentine?

Mr. VALENTINE. Mr. Chairman, I do want to ask one or two questions and I have a disadvantage in that I got here late and don't know just what all the testimony was. But I would like to find out—and perhaps Mr. McLoughlin would be the person that I should address this question to. The possibility of earthquakes and the human suffering and property loss which result from these tragedies is, of course, an international problem. Do we have an effective organized means of cooperating with our counterparts in other governments throughout the world to exchange information on the latest techniques in detection, and also in connection with evacuation and safety matters and things of that kind?

Mr. McLOUGHLIN. Mr. Valentine, the other agencies will be better prepared to respond to the questions about this exchange of information with other countries in the scientific arena. We clearly do get involved with the exchange of information. Dick Krimm who is with me today had a recent trip to China, along with other members from the U.S., to look at the earthquake programs in China.

We do take every opportunity to deal with exchange of information on preparedness aspects of the program, since that is our principal focus. An example is the U.S./Mexico planning project for San Diego/Tijuana. Although we are in the disaster relief business here in the United States, we are not at all in the disaster relief business in foreign countries. That is handled by the Office of Foreign Disaster Assistance in the Department of State.

Mr. VALENTINE. My other question, my last question, is this. Of course, in this country some sections are earthquake-prone, if that's the way to put it. There was an earthquake many years ago in Charleston, South Carolina. In my state, North Carolina, as far as I know there has never been an earthquake. There was a tremor in my district within the past several weeks, I'm told.

Do you believe, without getting into anything that might be controversial or without naming names, so to say, do you believe that the states that are primarily involved participate in this program to the extent of their ability, as a rule?

Mr. McLOUGHLIN. Mr. Valentine, when you say participate do you mean in terms of funding or do——

Mr. VALENTINE. Yes, yes.

Mr. McLOUGHLIN. Or do you mean in terms of being prepared for——

Mr. VALENTINE. In both. Funding to meet their own particular problems and in preparedness.

Mr. McLOUGHLIN. Certainly, the States do indeed make a major commitment to emergency management across the country. But it's spotty, and clearly it's spotty based on whichever State we're talking about. If we're talking specifically about earthquake, the State of California has put many more dollars into this probably than any other State in the country. They also have probably the more serious hazard.

On the other hand, we support funding in our agency for a full range of disasters. We have the Hurricane Preparedness Planning activity, we have the Civil Defense activity, we have Radiological Emergency Preparedness around nuclear power plants. The combination of all of those preparedness activities improves the preparedness and response posture of State and local governments. And certainly in your State, the State agency is equipped to handle a broad range of emergencies.

Mr. VALENTINE. Yes.

Mr. **Frederick**. Mr. Valentine, I respond for the Geological Survey to your two questions. On the matter of international relationship and our relationship with other countries, we do have substantial activities worldwide on earthquake research and earthquake prediction activities. Three countries, I guess, come to mind specifically in terms of coordinated research: Peoples Republic of China, Japan, and the Soviet Union.

For instance, we have a protocol with the Peoples Republic of China that involves installation of stations, specific prediction research, and other related activities.

We also have an agreement with the Department of State, Office of Foreign Disaster Assistance, to respond to requests from any country around the world, for which there are earthquakes. We have sent people to Mexico City, to South America, on many occasions. So we do have a very strong international relationship.

That works both ways. Input to us in terms of understanding. There's some strong research activities in other countries, and also to—we think it's an effective implementation tool for U.S. international policy in that regard, and I expect that applies across the table to the four agencies.

With respect to State participation in the program, I'd just comment in addition there. We have strong State programs, almost across the country. Specifically in California, we are working with the State Geological Survey, and the Office of Emergency Services, and they are putting a great deal of money into that program, mostly for purchase of equipment and studies in kind, basically.

I mentioned earlier in the testimony some regional application studies. We worked with the State of Utah and plan to work in the Pacific Northwest, where we'll be working with the States of Washington and Oregon. They will contribute a great deal to those programs.

In the southeastern part of the country—North Carolina, South Carolina—we work with the State geologists, primarily, and the emergency services organizations. So the States contribute a great deal.

From our program point of view, most services in kind, working with our scientists.

Mr. **Valentine**. Thank you.

Thank you, Mr. Chairman.

Mr. **Walgren** [presiding]. Thank you, Mr. Valentine.

The gentleman from California, Mr. Brown.

Mr. **Brown**. Gentlemen, forgive me for coming in late. I am not going to belabor any of these issues. If what I am asking has already been covered, why, just say so and I'll read the record later on.

Mr. Frederick, reading your testimony, I note that you say that it's necessary to reduce your program by the amount that's specified here in the earthquake program to support higher priority programs, while holding your overall budget about on a level with fiscal year 1987. What are the higher priority programs that you are continuing to support?

Mr. **Frederick**. Mr. Brown, the specific reason for the reduction in the earthquake program was essentially on two accounts: obviously the tight budget situation and the Gramm-Rudman-Hollings targets that we received, and also the necessity to cover a rather large increase in the cost of the Federal retirement system, and the pay cost for civilian employees.

Mr. BROWN. So—well, we recognize the importance of the retirement and pay, and the number you were given doesn't allow you to maintain then the earthquake programs. You mentioned specifically regional seismic networks will be reduced. Could you, if you haven't already, stipulate just where you are making those reductions?

Mr. FREDERICK. We can provide additional information for the record, Mr. Brown, but basically we are looking at two small networks in the Aleutian chain, and perhaps one in the Pacific Northwest.

Mr. BROWN. You didn't have to cut back on the seismic networks in Parkfield or——

Mr. FREDERICK. No, sir. We——

Mr. BROWN. That will continue?

Mr. FREDERICK. We are continuing with the full cooperative program in the Parkfield area.

Mr. BROWN. We have been disturbed in past years that the—the instrumentation on some of these areas of high seismic activity were—were not as—moving ahead as—as fully as we might have liked, that you might have liked or that we might have liked. Do you think the situation is reasonable at the present time?

Mr. FREDERICK. We think, Mr. Brown, that's reasonable considering the overall budget constraints, and how we have to make those judgments to put together our program.

Our scientists would like to have more instrumentation in certain parts of California, including Parkfield, but we don't believe at this point, considering what we know about the earthquake phenomena, that there are serious gaps.

Mr. BROWN. I hope you're right.

I have no further questions.

Mr. WALGREN. Thank you, Mr. Brown.

The gentleman from New York, Mr. Nowak.

Mr. NOWAK. Thank you, Mr. Chairman.

I would like to ask one general question here of all our panel witnesses who, I think, come highly qualified, and that is simply does your specific agency, each of you, really have any plans to focus additional research in the Eastern United States for fiscal 1988? And I think, Mr. McLoughlin, if you would start that off, and we could get your opinions right down the line.

Mr. McLOUGHLIN. We are supporting right now an effort that is looking at the most appropriate earthquake loss methodology to be used in the U.S., but also specifically for earthquakes east of the Rockies. You know, there's essentially good methodology available for west of the Rockies, but we are taking a look at all current methodologies and if that effort is not completed in 1987, we will be completing it in fiscal year 1988.

We do intend to certainly support and continue to support the earthquake preparedness efforts on the East Coast, and in the Central U.S. in 1988.

Mr. NOWAK. Yes, sir.

Mr. **Frederick**. The Geological Survey program for fiscal year 1988 at eastern universities doing related studies, projects, and the like will continue at about level, that's about $2 million, just under $2 million.

Mr. **Nowak**. Dr. Suh?

Mr. **Suh**. Well, the NSF program is evenly divided between the east and the west part of the nation, and the fact that we established this major earthquake engineering research center at SUNY-Buffalo indicates that we regard the earthquake possibilities, in all parts of the nation, to be of concern to us as researchers. So in all cases we feel that our programs are fairly well balanced.

I would like to have Dr. Hays, who represents the earth sciences part, to speak on that issue also.

Mr. **Hays**. In the earth sciences, we have recently issued a program announcement in this area, and I have furnished a copy of that for the record. That announcement identifies four areas of particular opportunities for earthquake research. One of those areas is the area of intraplate earthquakes. These are earthquakes that occur in the interiors of plates, not at the plate boundary, and it is this type of earthquake that presents the chief hazard in the East.

Mr. **Nowak**. Fine.

Mr. **Wright**. At the National Bureau of Standards, we will initiate a program this year and continue it next year to study the behavior mechanisms of modestly reinforced masonry walls. Structural masonry is very popular in the Eastern United States. Most of it at the present time is unreinforced. Practitioners in the Eastern United States are reluctant to go to the very heavy seismic reinforcement that's common in California and other states where earthquakes are very frequent.

So we feel these new results on the performance of modestly reinforced masonry walls will be very helpful to seismic safety in the Eastern United States.

Mr. **Brown**. Will the gentleman yield to me for one moment?

Mr. **Nowak**. Surely, Mr. Brown.

Mr. **Brown**. I am pleased with the responses that you have given to these questions. I feel personally that one of our lacks in the past has been a full, adequate, national understanding of the significance of the earthquake hazard, and the need for additional effort focused on mid and Eastern—mid-country and Eastern regions that do pose, as we know from historical facts, serious threats. While, of course, I regretted the loss of our—of the research facility to New York, I wasn't all that upset about it, because I felt that it did help us to create a broader base of understanding of the problems with the Eastern United States, and I wanted the record to reflect that.

Mr. **Nowak**. Thank you very much, Mr. Brown.

I wonder if, Dr. Suh, you could just spend a second here and tell us what is being done, if anything, really, to promote the transfer of the research results, you know, to the various user communities out there.

Mr. **Suh**. Well, NSF is doing a number of things. We have for a number of years supported the effort at the University of California, Berkeley, to disseminate information through NISEE, the National Information Center. I cannot give you exactly what NISEE stands for. It's an acronym for information dissemination, located at the University of California at Berkeley.

In addition to that, one of the major elements of the new center we have created at SUNY-Buffalo, is technology transfer. They have a separate organization within the center dealing with information gathering, as well as dissemination.

We feel that, in addition to these things, we ought to do other things, such as perhaps the use of compact disks to store research information, and to distribute all the available research results to all the users by sending these disks out to the community. So we are doing a number of these things, and obviously we can be doing a lot more, and we are trying to come out with ideas that make sense and implement them as we can justify them in time.

Mr. NOWAK. Thank you.

Thank you very much, Mr. Chairman.

Mr. WALGREN. The gentleman from Iowa, Mr. Nagle?

Mr. NAGLE. I don't have any questions, Mr. Chairman.

Mr. WALGREN. Let me ask Dr. Hays, as I understand it, the earthquake effort within the Earth Science Division in the National Science Foundation makes an effort in this area, but it's not a line item in the budget. How do these programs compete for your attention as opposed to other efforts that you are also pursuing?

I gather an earthquake is—is a classic unsqueaky wheel, because it doesn't speak out presently.

Mr. HAYS. They do very well, indeed. And as you probably noticed in the last few years, the Foundation has placed particular emphasis on earth sciences through its continental lithosphere program. Many of the projects within that program also are important for the earthquake hazard reduction program. The Cajon Pass project that I mentioned is of that type. So is the IRIS program. So, in fact, based purely on scientific priorities, research in this area is clearly a high priority area within the earth sciences and within the National Science Foundation.

Mr. WALGREN. So you put no special effort on earthquake research at all?

Mr. HAYS. We don't find it necessary. We find that, in fact, earthquake research is a powerful part of the earth sciences program.

Mr. WALGREN. But that is a matter of happy circumstance, I gather.

But now, Dr. Nam Suh, is that the same thing for the engineering side?

Mr. SUH. Well, in engineering, we have taken steps to identify earthquake research as a line item, and then we have watched it over the years, and we have tried to maintain the momentum in this area.

What we have decided to do was to see if we can facilitate technology transfer by involving States. This is one of the many reasons why we have established this research center at Buffalo, and through that, it turns out that we have also increased the funding for earthquake research significantly by some $7 million and, therefore, we feel that we have given sufficient attention to this.

And as to why engineering is identifying those figures as a budget element, whereas in geosciences they do not do that, I can fully explain. In engineering we are dealing with a large number of different issues other than earthquakes, so unless we identify that as an independent element, it may get lost in the shuffle. So in order to make sure that we identify the activity and maintain a thrust in this area in line with the National Earthquake Hazards Reduction Act that you passed in Congress, I think we are trying to fulfill our part of the obligation.

Mr. **WALGREN**. I gather there must be substantial contact between yourself in Engineering and the Bureau of Standards effort in building technology. Would that not be true?

Mr. **SUH**. Well, for one thing, the National Science Foundation is co-funding with FEMA the effort that NBS is doing to study whether or not we should establish a large test facility, and in addition to that, it turns out that Dr. Lyons and I are in constant contact in discussing all the things we are doing within the National Science Foundation, and certainly also within the National Bureau of Standards, in areas where we have common interests.

Mr. **WALGREN**. Both of you are looking at this large shake table, is that——

Mr. **SUH**. That's the study being sponsored by the National Science Foundation.

Mr. **WALGREN**. And where is that now in your perspectives? Dr. Lyons?

Mr. **LYONS**. We have submitted for the record the phase one report, which was the study of the research agenda for such a facility. At the moment we have not decided whether to proceeed with the second, third and fourth phases of that study. That's a matter that's handled by this group as a whole, our policy coordinating group, and we decided a year or so back to break this whole question of the large testing facility into a four-phase operation, do the first phase, and then see whether the results of that were compelling enough to warrant funding in the subsequent phases.

Mr. **WALGREN**. And the third phase is what you would like to do with it; is that the idea?

Mr. **LYONS**. The first phase is a—the report is a summary of the definition of need for such a facility, not by NBS, but by the community. We were the convenor of a workshop, we talked to lots of people, we got advice from as many different places as we could. So this report is essentially a consensus of the earthquake community as to what is needed, by way of research results.

Now that does not define, necessarily, what sort of test facility will come out of this as a recommendation.

Mr. **WALGREN**. I see. Let me ask you, Dr. Lyons, on the existing building effort, is that—would that largely be in the Center for Building Technology?

Mr. **LYONS**. All of it. Yes, sir.

Mr. **WALGREN**. Could you describe that program briefly? What are you doing there? How much money are you spending, and what are we getting for it?

Mr. **LYONS**. In the earthquake program or——

Mr. **WALGREN**. In the existing—yes, I gather there is an existing building thrust of the earthquake program; is that right?

Mr. LYONS. Yes. We have about a million dollars in total funding. Half of it is NBS money and half of it is FEMA money, plus this study money which we were just discussing, which is a smaller piece.

And in that program, we have worked very hard in supporting the rest of the community in drafting these proposals for improved regulations for providing seismic resistance in buildings, and I touched on that and the Interagency Committee aspect of it, as well as the Building Seismic Safety Council and related activities.

So there's been a series of standards-related things, and then there is the research program that I hit on lightly, which Dick Wright was just talking about, the masonry shears, which is one part of the program. I talked about diagonally braced steel structures and the large bridge pier research, which is kind of a summary of what we do. But it's a substantial research program.

I think the point to make, Mr. Chairman, is that we have, as the core of our Center for Building Technology, the Structures Division, and these questions of seismic resistance really run to the heart of the current state of the art of structural engineering. So the problems we're wrestling with in the earthquake program are very important to civil engineers in general, very important to the regulatory structure.

In response to your earlier question of my colleagues, I think we want to do these things whether or not we have a special emphasis, whether or not we had a special earthquake program and a special earthquake hearing. The seismic questions are really very important to the structural engineers.

Mr. WALGREN. Is the total effort a million dollars?

Mr. LYONS. The total earthquake program at NBS is just shy of a million dollars.

Mr. WALGREN. And that includes both the standards function and the structural research, I gather.

Mr. LYONS. Yes, that's correct.

Mr. MCLOUGHLIN. Mr. Chairman, may I add to that answer, since your focus was on existing buildings. It is true that we underwrite a portion of the work that's being done at NBS that Dr. Lyons just mentioned.

In addition to that, we are doing some additional work out of our funds on existing buildings. We are following the five-year plan that was laid out by the work group dealing with this area, and it includes a set of how-to books that we're working on right now for rapid screening of existing buildings, for dealing with evaluating the buildings that are identified as hazardous, evaluating what should be done and what can be done to those buildings, a third one on setting up priorities. For rehabilitation, a fourth one that deals with typical costs for rehabilitating existing buildings, and a last one dealing with simply a history of costs, what it actually has cost to rehab existing buildings.

Mr. WALGREN. You say you're underwriting part of NBS' effort. How much money are we talking about?

Mr. MCLOUGHLIN. We put about a million and a half dollars of our $4.5 million worth of program funds into the seismic design and construction activity. That includes new buildings, existing buildings, and lifelines, for which we are going to get a new work plan, probably next month, that will come out of the workshop process.

Mr. WALGREN. And how much of that would go into existing building research underwritten at NBS?

Mr. McLOUGHLIN. FEMA funds NBS to provide assistance in all areas of the seismic design program at approximately $300,000 to $400,000 a year.

Mr. LYONS. $400,000 to $500,000.

Mr. WALGREN. $400,000. And then how much of the Building Technology Center monies go right towards this function?

Mr. LYONS. An equal amount.

Mr. WALGREN. An equal amount. And that makes up the million?

Mr. LYONS. That's not just existing buildings. That's everything that I was talking about.

Mr. WALGREN. Well, I guess—fine.

Dr. Suh, where are we on the societal response program which, as I understand it, was a separate budget item several years ago, but is not no longer identifiable per se?

Mr. SUH. Well, what we have done is, when, at one time we had to reduce the budget, we reevaluated everything we did in the earthquake engineering research programs at NSF, and then we integrated the societal response part throughout the NSF program in engineering. So much of that now resides in the earthquake systems integration part of the earthquake engineering program.

So it's not that we are not supporting research in this area, but it's just simply diffused into all of our programs. It is correct that we do not have a line item or sub-element items that you can look at and say, "Yes, there it is." But we are not dropping it as a research issue.

Mr. WALGREN. Well, I think from our standpoint, certainly we want to emphasize its importance and do everything we can to make sure that it's not forgotten.

Well, are there other questions that people would like to ask the panel?

[No response.]

Mr. WALGREN. If not, on behalf of the committee, we appreciate your efforts in this area, and we appreciate your responsiveness, and we want to pursue you in the area as well, so we will be talking to you.

Thank you.

The second panel today is made up of Thomas Tobin, who is the Executive Director of the California Seismic Safety Commission; Robert Ketter, the Director of the National Center for Earthquake Engineering Research at the State University of New York at Buffalo; Donald Mabey, the Deputy Director of the Utah Geological and Mineral Survey; and Edward Fratto, the Earthquake Program Manager for the Civil Defense Agency associated with the Commonwealth of Massachusetts.

If you folks would come forward, we appreciate your coming, and as I said at the outset, written submissions that you'd like to make will be reproduced word for word, and therefore will be there for those who review this area, and please use the verbal presentation as an opportunity to focus attention on points that you feel should really be underscored, and then that will help direct the others who then read the written statements as well.

And in the interest of time, if you would know that somewhere after five minutes and beyond is sort of starting to get us late, we'd appreciate your just keeping that in the back of your mind.

Let's start in the order that we introduced you to the record, and first would be Mr. Tobin.

STATEMENTS OF L. THOMAS TOBIN, EXECUTIVE DIRECTOR, CALIFORNIA SEISMIC SAFETY COMMISSION, SACRAMENTO, CA, ACCOMPANIED BY DR. WILFRED IWAN, CHAIRMAN, CALIFORNIA SEISMIC SAFETY COMMISSION AND PROFESSOR, CALIFORNIA INSTITUTE OF TECHNOLOGY; DR. ROBERT L. KETTER, DIRECTOR, NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH, STATE UNIVERSITY OF NEW YORK AT BUFFALO, BUFFALO, NY; DONALD R. MABEY, DEPUTY DIRECTOR, UTAH GEOLOGICAL AND MINERAL SURVEY, SALT LAKE CITY, UT; AND EDWARD FRATTO, EARTHQUAKE PROGRAM MANAGER, COMMONWEALTH OF MASSACHUSETTS, CIVIL DEFENSE AGENCY AND OFFICE OF EMERGENCY PREPAREDNESS, FRAMINGHAM, MA

Mr. **Tobin**. Chairman Walgren and members of the committee, it's a pleasure for us to be invited today to speak before you.

I would first like to introduce Dr. Wilfred Iwan, who is Chairman of the California Seismic Safety Commission and a professor at the California Institute of Technology, and I would also like to request, as others have, that a full copy of my written statement be entered into the record.

The California Seismic Safety Commission was created in 1975 to provide a focal point for earthquake policy. It's most important responsibility is to serve as a watchdog, mandated to ensure the earthquake safety, hazard mitigation, emergency planning, and response and recovery are given proper attention and are not lost in the turbulent sea of issues and funding constraints that face our state.

The Commission is also responsible for preparing and annually revising a five-year earthquake hazards reduction program. This program was written to reduce earthquake hazards statewide significantly by the end of the century. This is the California goal, and we invite you to adopt this as a nationwide goal as well.

The National Earthquake Program has been successful in California, and although California has a well-developed hazard reduction program, much remains to be done to protect life and property, and, of course, we urge you to reauthorize the Act and to consider some amendments which will address recommendations that I will make later to strengthen the program.

First of all, Mr. Chairman, you asked me to comment on the adequacy of the overall budget for the fiscal year 1988 and the impact that it will have on earthquake programs and policy in California.

The Federal program has been underfunded since its inception, and the situation is getting worse. The program was funded in 1977 at a bare minimum amount, and since then, funding has remained essentially level, even though the odds for damaging earthquakes increase every day, and the demand for assistance has increased dramatically across the nation. And since the program began, inflation has chopped the real-dollar value in half. The shortfall simply means that critical research is not being done, that programs to assist State and local governments are outrageously underfunded, and the nation's progress in earthquake hazard reduction suffers.

The fiscal year 1988 budget will cause cuts in studies regarding the buildup of strain across California's faults. It will mean fewer dollars to help local governments and private businesses apply what we already know, and it will mean that some of our researchers and laboratories will not be able to carry out vital studies on hazardous buildings, and it will mean that more people will die than have to.

The fiscal year 1988 budget request for $65 or $67 million amounts to only 25 cents per American. That is the price of one game in a video arcade. The Federal Government's interest in California alone justifies spending more on the program. The huge federal cost of disaster aid, helping rebuild our buildings and economy, all justify a stronger program.

Simply put, we can pay some now, or we can pay a lot more later in dollars and in lives.

You should consider first the question of leadership. Leaders determine how aggressive the program will be, what it will emphasize, whether budgets will be increased or cut, what efforts are of high priority, and whether the program will progress in a coordinated, effective manner.

The Federal program needs stronger leadership. The 1980 amendments to the Act made FEMA the lead agency. The amendments empowered FEMA to set goals and priorities, but did not see that other agencies have to carry them out. Regardless of the lack of mandate to lead, the funding since 1980 has not been enough for effective leadership.

At present, the program is fragmented. Except for your committee, as was pointed out, the funding process is completely fractured between the agencies and OMB and the Appropriations Committees.

We recommend that the budget should be viewed as one item. Make it a line item in the President's budget.

Earthquake programs make up but a small fraction of each agency's budget. Thus high-level management support is lacking. Nationwide leadership is also missing. Who speaks at the national level for earthquakes? And if he can, what is he saying? In California, we can't hear.

We recommend creating a permanent independent commission to provide visible leadership and to guide the national earthquake hazards reduction program. The situation is similar to that in California, where 25 agencies each have a small piece of our earthquake program. A commission would allow us to bring together representatives of each level of government, with representatives from several disciplines and interests. Earthquake hazard reduction is far too important to have a leaderless program lost among competing demands and priorities in the crush of everyday business in Washington, D.C.

Program priorities are also important. Consider at this time, we will accomplish the goals of the Act if we focus nationwide on two objectives: First, reduce existing hazards, and second, prepare plans and develop the capability for an emergency response to region-wide disasters.

Direct research to these objectives. Assist local and state agencies to address these issues. Direct all federal agencies to use their programs to address these objectives. See that Federal agencies forge incentive programs to encourage local governments and private owners to address these objectives.

Last month, FEMA forwarded a draft Executive Order to OMB that, when approved, will require all Federal agencies to incorporate seismic design into new buildings, regulated or supported by the Federal Government. It also addresses existing hazardous buildings. If approved, this Executive Order is tangible evidence that the Federal Government means business.

I ask you to use this committee's oversight responsibility to make sure that that Executive Order isn't scuttled by OMB and never sees the light of day. This frankly can help us dramatically in California if it's carried out.

Mr. Chairman, you also asked for comments on how well research results in Federal programs are being incorporated into seismic safety practices in California. We believe research results are being incorporated in seismic safety policies to an unparalleled extent. Our building codes are constantly being revised. We have passed over 30 State laws in the last ten years. We have initiated planning efforts with local governments to respond to a possible prediction.

Rather than resisting new information, we demand it. Thus on one hand, research results are quickly used to save lives, and our preparedness projects, SCEPP and BAREPP, are wildly successful at transferring the latest information into concrete action. Yet on the other hand, much more needs to be done at the local level to reduce hazards.

In my written testimony submitted to you, I have listed many success stories, but I have to stress that while we're proud of our many accomplishments at the State and local government levels, and we are proud of the exciting programs carried out by the private sector, only a handful of our 485 cities and counties and thousands of businesses have been reached.

Assistance programs and programs to transfer existing knowledge and technology must be given equal priority to efforts to extend our knowledge. Recognize that ultimately local governments and the private sector are responsible, and unless you fund a long-term effort, this program will never be as successful as it could be.

In California, we have yet to reach that critical mass where a majority of the cities and counties and businesses are addressing earthquake hazard reduction. When we reach that point, the earthquake hazard reduction program will become part of our lives, the national program will be a success, and we will have met our goal by significantly reducing earthquake hazards.

Mr. Chairman, I would like to invite you and your committee to California to view our progress, and I would be pleased to answer questions later on.

Thank you very much.

[The prepared statement of Mr. Tobin follows:]

Written testimony to the

SUBCOMMITTEE ON SCIENCE, RESEARCH, and TECHNOLOGY

Science and Technology Committee

House of Representatives

on the

NATIONAL EARTHQUAKE HAZARDS REDUCTION ACT

by

L. Thomas Tobin, Executive Director

California Seismic Safety Commission

March 10, 1987
Washington, D.C.

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INTRODUCTION

This statement is offered on behalf of the California Seismic Safety Commission in support of reauthorizing the National Earthquake Hazards Reduction Act (NEHRA). This statement will describe the importance of NEHRA to, and some of its accomplishments in, California; describe California's earthquake hazard reduction programs; and recommend actions to strengthen the federal program.

The Seismic Safety Commission is an independent state commission established in 1975 to advise the Governor, Legislature, state and local agencies, and the private sector on earthquake safety policy.[1] It is an independent agency composed of 17 commissioners chosen for their expertise and experience. Fifteen of the commissioners are appointed by the Governor upon consent of the Senate, one commissioner is from the Senate, and one is from the Assembly. The Commission investigates earthquakes, studies earthquake-related issues, and recommends to the Governor and Legislature policies and programs needed to reduce earthquake hazards. A further listing of the Commission's responsibilities is provided in Figure 1.

Although the Commission has a number of responsibilities, its most important role is to serve as a "policy watchdog," charged with ensuring that earthquake safety, hazard mitigation, emergency planning and response, and recovery are given proper attention and are not lost among the issues and funding constraints that affect the state.

The Commission and many of its members have worked to establish the National Earthquake Hazards Reduction Act. Present and former commissioners were and continue to be active on expert review panels such as those that led to the National Earthquake Hazards Reduction Program's (NEHRP's) five-year plan and the current review of the plan. California will continue to develop new and more effective ways to reduce earthquake hazards, and share its experience and expertise in a cooperative manner with the federal program.

At present, the Commission has a cooperative agreement with the Federal Emergency Management Agency for the Bay Area Regional Earthquake Preparedness Project. Half of the project's $750,000 budget is provided by the Commission with state General Fund money and half by FEMA funds appropriated under the National Earthquake Hazards Reduction Program. Since 1977 the Commission has administered $4,778,350 NEHRA funds.

The Commission is thoroughly familiar with the federal program and, perhaps, is in a unique position to offer advice. It is in light of its responsibilities, and its direct experience in earthquake hazard reduction programs, that the Commission presents its testimony.

CALIFORNIA SEISMIC SAFETY COMMISSION

RESPONSIBILITIES

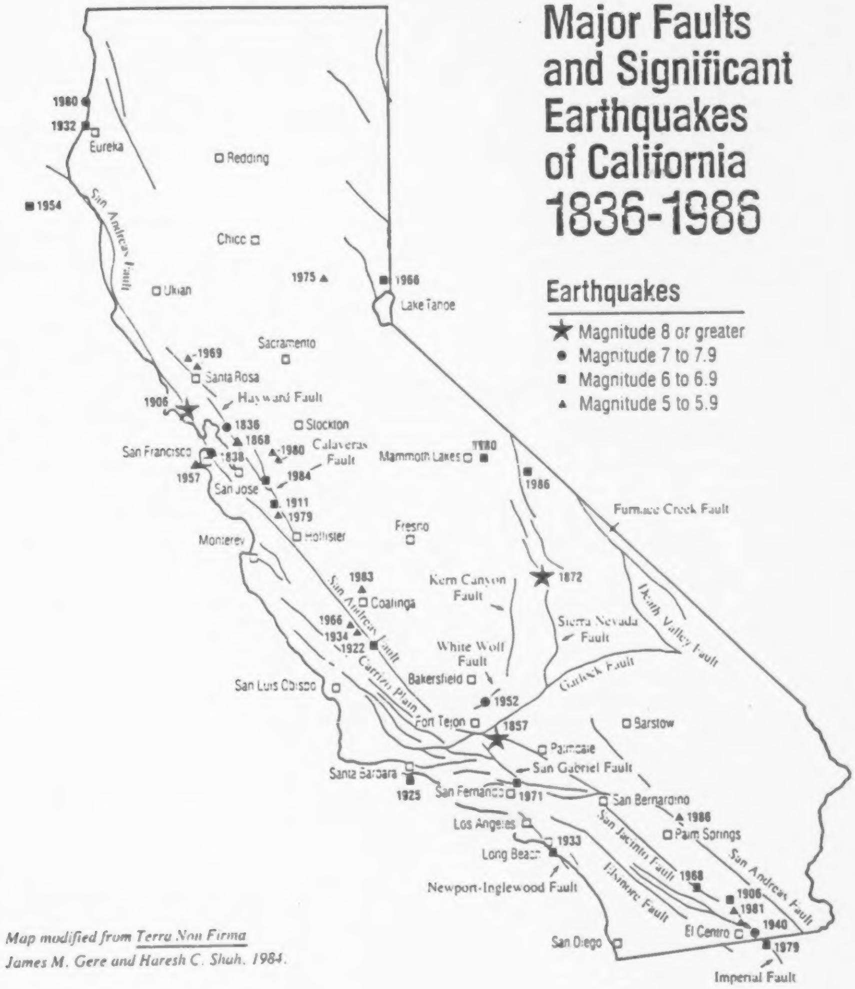
- Recommending to the Governor and Legislature policies and programs needed to reduce earthquake hazards;
- Reviewing earthquake-related activities funded by the state;
- Providing consistent policy direction for earthquake-related programs for agencies at all government levels;
- Proposing and reviewing earthquake-related legislation;
- Conducting public hearings on earthquake safety issues;
- Requesting state agencies to devise, modify, or incorporate criteria and standards that promote earthquake safety;
- Conducting investigations following damaging earthquakes on damage, recovery, and reconstruction efforts;
- Gathering, analyzing, and disseminating seismic safety information, stimulating research, and encouraging training;
- Preparing and revising a five-year action program to reduce earthquake hazards statewide significantly by the end of the century;
- Assisting local governments to identify the most seismically hazardous buildings in California and develop plans to mitigate their hazards;
- Administering the California Earthquake Education Project curriculum for use by public and private schools to help teach science and earthquake preparedness in grades four through eight; and
- Establishing the Southern California Earthquake Preparedness Project (SCEPP) in 1981 and the Bay Area Regional Earthquake Preparedness Project (BAREPP) in 1984.

FIGURE 1. California Seismic Safety Commission Responsibilities

THE THREAT IN CALIFORNIA

Scientists agree that a major earthquake can strike California at any time. The odds are 50-50 that a major earthquake will strike a California metropolitan area within the next twenty to thirty years.[2] Moreover, Californians must also be concerned about damaging moderate earthquakes, which will continue to strike much more frequently than the major quakes. For example, the 1971 earthquake at Sylmar, only a magnitude 6.6, caused over $2.6 billion in damages and took 64 lives. The 1983 magnitude 6.7 Coalinga earthquake caused $7.5 million in damage. During the last 140 years, more than 83 earthquakes over magnitude 6 have shaken California. (Figure 2 illustrates the location of major faults and significant earthquakes.) California has responded by developing an active hazard reduction program that will be explained in more detail later in this testimony and in Appendies A and B.

When a major event – that is, over magnitude 7 – strikes a metropolitan area, the damage will be widespread. Forecasts indicate that thousands of lives may be lost, that tens of thousands may require hospitalization, and that hundreds of thousands will be left injured and homeless. Estimates of direct physical damage go as high as $50 to $70 *billion*.[3] Unless we substantially step up our hazard reduction programs, and fate allows us ten to fifteen years to carry them out, the next California earthquake will be a catastrophe with national consequences. And the federal government has an interest in California earthquakes far beyond its legitimate concern for the welfare of Californians.


Major Faults and Significant Earthquakes of California 1836-1986
Earthquakes
★ Magnitude 8 or greater
● Magnitude 7 to 7.9
■ Magnitude 6 to 6.9
▲ Magnitude 5 to 5.9
1980
1932
Eureka
Redding
1954
San Andreas Fault
Chico
1975
1966
Lake Tahoe
Ukiah
Sacramento
1969
Santa Rosa
Hayward Fault
1906
1836
Stockton
1868
San Francisco
1838
1980
Calaveras Fault
1957
1984
San Jose
1911
1979
Mammoth Lakes
1980
1986
Furnace Creek Fault
Fresno
Hollister
Monterey
1983
Coalinga
Kern Canyon Fault
1872
Death Valley Fault
San Andreas Fault
1966
1934
1922
Sierra Nevada Fault
White Wolf Fault
Garlock Fault
Carrizo Plain
Bakersfield
San Luis Obispo
1952
Fort Tejon
1857
Barstow
Palmdale
San Gabriel Fault
Santa Barbara
1925
San Fernando
1971
San Bernardino
1986
Palm Springs
Los Angeles
1933
Long Beach
San Jacinto Fault
Elsinore Fault
San Andreas Fault
1968
1906
1981
Newport-Inglewood Fault
1940
El Centro
San Diego
1979
Imperial Fault

Map modified from *Terra Non Firma*
James M. Gere and Haresh C. Shah, 1984.

Figure 2. Major Faults and Significant Earthquakes

THE FEDERAL STAKE IN CALIFORNIA

The federal government obviously has a large presence in California, but the importance of its earthquake programs to the nation may not be as clear. Earthquake hazard reduction programs are of direct interest to federal activities. In the aftermath of a large earthquake in California, the federal government will be forced to respond with billions of dollars in aid to help rebuild the infrastructure and economic base. Federal facilities and contractors will be damaged. A brief review of California's contribution to the nation's defense illustrates the point.

The Department of Defense alone employs over 340,000 military and civilian persons at dozens of bases and installations in California. Major defense and space contractors in California include Rockwell International, Hughes Aircraft, Lockheed, General Dynamics, McDonnell-Douglas, Summa, Northrup, and TRW. (Figure 3 illustrates the location of key military bases and defense contractors.) California businesses carry out over 14 percent of the federal government's nondefense contracts; California firms have been awarded from 15 to 20 percent of all prime defense contracts since 1963; and in 1984, 52.5 percent of weapons procurement, 38.6 percent of missile and space equipment, and 25 percent of aircraft orders were filled in California.[4]

California also plays an important role in the economy of the nation and of Pacific Rim countries. Annual exports to Pacific Rim countries exceeds $65 billion. Banking interests estimate that loss of one major bank's data processing capability will have crippling effects on this activity. If the loss lasts three days the California economy will be impacted; if the loss lasts five days, the nation's economy will be impacted; and if the loss lasts seven days, the world economy will be impacted. If several banks in a region loose data processing capability, the impact on the economy will be devasting.[5] These far-reaching effects are caused by the volume of financial transactions that take place in the Los Angeles and San Francisco regions.

It is clear that the federal government's exposure to earthquake risks in California and in the other seismically active states is great, yet the federal government's support of earthquake safety programs is comparatively small. The present funding level of $65,078,000 per year represents about 25 cents per American - the cost of one game at a video arcade. The federal budget appropriates less than one of every $15,000 dollars in the federal budget for earthquake hazard reduction even though so many lives, so much activity, and the nation's defense capability are at stake.

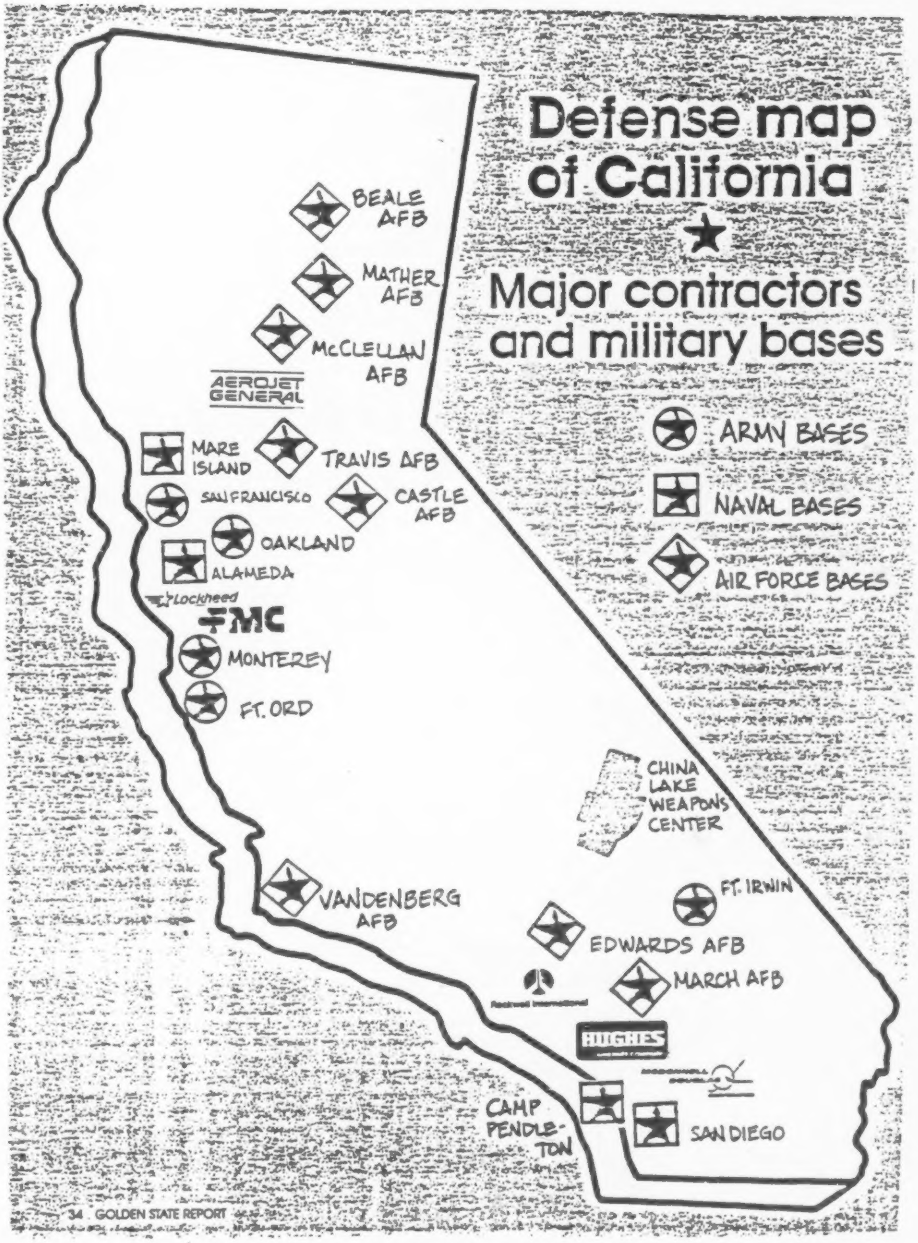

Defense map of California
Major contractors and military bases
ARMY BASES
NAVAL BASES
AIR FORCE BASES
BEALE AFB
MATHER AFB
McCLELLAN AFB
AEROJET GENERAL
MARE ISLAND
TRAVIS AFB
SAN FRANCISCO
CASTLE AFB
OAKLAND
ALAMEDA
Lockheed
FMC
MONTEREY
FT. ORD
CHINA LAKE WEAPONS CENTER
VANDENBERG AFB
FT. IRWIN
EDWARDS AFB
Rockwell International
MARCH AFB
HUGHES
McDONNELL DOUGLAS
CAMP PENDLE-TON
SAN DIEGO
34 . GOLDEN STATE REPORT

Figure 3. **Defense Map of California** (Golden State Report, July 1986)

PROGRESS IN HAZARD REDUCTION

Progress has been made, albeit slowly, in spite of inadequate funding of NEHRP. Awareness of the earthquake threat, and of mitigation measures, has improved. A public opinion poll conducted on December 17, 1985 by Mervin Field indicated that 89 percent of Californians are aware that their area is likely to be damaged by an earthquake. This statistic represents an increase of 16 percent above the 1979 awareness level. But awareness is not enough. The same poll also revealed that an equal number, 89 percent, were not worried. There is a crucial gap between being aware and taking action, between having good intentions and actually reducing hazards at home and in the workplace.

State and local government and private sector programs have also grown. The level of planning and preparation in public and private schools has increased dramatically. All of these improvements since NEHRA was passed are due to cooperative efforts of the NEHRP agencies - FEMA, USGS, NSF and NBS - and the State of California. Although it may not be possible in this testimony to detail precise cause-and-effect linkages between the federal, state, local government, and private sector programs, it is clear that our progress to date has been helped and supported by NEHRP. A brief summary of progress in earthquake hazards reduction since passage of NEHRA will better illustrate the point that federal dollars spent in California will save lives because the laws, organization, and wherewithal to accommodate information provided by NEHRP is in place.

State Government Accomplishments

California is the state most at risk from earthquake hazards, and it has responded with the most comprehensive state earthquake program in the nation. State-funded programs have been strengthened to address life-threatening hazards and improve emergency response. Since 1977, state funding for these programs has grown by 56 percent, from $16 million to $25 million during FY 85/86.

Figure 4 illustrates the state agencies and expenditures for earthquake safety programs; a more detailed summary of key state programs which illustrate the scope of our existing effort, is in Appendix A.

Since 1977 the state has enacted over thirty new laws creating a number of new activities and committing new funds. Figure 5 summarizes recent legislation. No other state that has mounted a similar effort, and there is no other state where so much more is needed.

SUMMARY OF ESTIMATED 1985-86 STATE GOVERNMENT EXPENDITURES FOR EARTHQUAKE HAZARD REDUCTION ACTIVITIES

AGENCY	ACTIVITY	1985-86
Department of Conservation—Division of Mines and Geology		
	• Basic Investigations	$ 466,000
	• Geological Information	550,000
	• Hazards Reduction	1,768,000
Office of Emergency Services		
	• Earthquake Prediction Response	3,072
	• Earthquake Response Planning	1,035,000
	• Public Information on Earthquake Safety	69,968
California Energy Commission		
	• Energy Commission Power Plant Certification	425,000
Department of General Services, Office of the State architect		
	• Essential Services Buildings	95,000
	• Structural Safety of Hospitals	(4,771,000)
	• Structural Safety of Schools	3,651,000
Office of Statewide Health Planning and Development		
	• Building Safety Board	8,000
	• Hospital Construction Review	12,899,000
Department of Insurance		
	• Probable Maximum Loss	31,196
Public Utilities Commission		
	• Bay Area Rapid Transit Earthquake Preparedness Plan	6,000
	• Utilities Earthquake Preparedness Plan	19,000
Bay Conservation and Development Commission		
	• Engineering Criteria Review Board	10,000
Seismic Safety Commission		
	• Bay Area Regional Earthquake Prepardensss Project	375,000
	• California Earthquake Education Project	175,000
	• Activities	596,000
Department of Transportation		
	• Bridge Retrofit Program	602,140
Department of Water Resources		
	• Operations and Maintenance of Seismic Instruments	487,000
	• State Water Project	410,000
	• Safety of Dams	340,000
University of California		
	• Seismographic Station	100,000
	• Earthquake Engineering Center	500,000
TOTAL		**$24,916,256**

Figure 4. Summary of California State Expenditures

SEISMIC SAFETY LEGISLATION IN CALIFORNIA: 1979 TO 1987

1979-1980

- Authorized the Seismic Safety Commission to issue subpoenas.

- Permitted local jurisdictions to lower building standards for the rehabilitation of pre-1933 buildings.

- Required the Seismic Safety Commission to do a study on Earthquake Hazard Reduction and Prediction.

- Established the Southern California Earthquake Preparedness Project.

1981-1982

- Required mobile home seismic bracing devices to be state certified safe before sale.

- Created the California Earthquake Education Project.

- Authorized cities and counties to sell limited obligation bonds for the purpose of rehabilitating pre-1933 buildings.

1983-1984

- Required essential services buildings be designed and built to resist earthquake forces.

- Required schools to establish earthquake emergency procedures.

- Created the Bay Area Regional Earthquake Preparedness Project.

- Required the Seismic Safety Commission to study the Coalinga earthquake.

1985-1986

- Required most cities and counties to inventory pre-building code buildings and to draft a mitigation program by 1990.

- Established a California Center for Earthquake Engineering.

- Extended the Southern California Earthquake Preparedness Project and the Bay Area Regional Earthquake Project to 1990.

- Established a study for an earthquake early warning system.

- Required the state to develop with the federal government an earthquake prediction system on the San Andreas fault.

- Created the Earthquake Emergency Investigations Account for purposes of post-earthquake investigations by state agencies.

- Requires careful checking of private school plans and construction.

Figure 5. Recent Seismic Safety Legislation Enacted in California

Local Government Accomplishments

It is difficult to summarize the earthquake hazard reduction efforts underway in each of the state's cities and counties. The local level of government is the one most directly concerned with earthquake safety, since it has primary responsibility. In California, local governments are responsible for building code enforcement, land use planning, emergency response, housing programs, redevelopment, and much of the recovery effort.

While a number of outstanding local government programs (described in Appendix C) have been initiated to identify and strengthen hazardous buildings, to reduce risks to government facilities and operations, to plan for responding to a prediction and to a disaster, and to prepare for recovery. Unfortunately, only a tiny minority of California's five hundred local jurisdictions as yet have such programs.

Because of the magnitude of the earthquake threat, local government must look to the state and federal governments for leadership, incentives, and financial resources. The federal program must be adapted so that it better responds to this situation.

Private Sector Accomplishments

It simply makes good sense for businesses to manage risk, and earthquake risks can be dealt with as any other risk. Insurance industry statistics indicate nearly two-thirds of all businesses fail following a disaster for which they were not prepared. In short, corporate officers have a fiduciary responsibility to protect corporate assets by preparing for an earthquake.

Seismic safety efforts carried out by private businesses are difficult to summarize. Though there has been a general lack of preparedness planning by the majority of firms, great progress has been made by some businesses, as described in Appendix D.

It is clear that industry is doing things never heard of just ten years ago, but many more such programs are needed. They will happen only if the federal government demonstrates that it takes earthquakes seriously and is willing to encourage work with the private sector to reduce hazards and develop emergency response capability.

Implementation of NEHRA in California

The NEHRP and predecessor programs have provided California with invaluable assistance in seismic safety activities. Government policies in California at the state and local levels have reacted to research and discoveries sponsored or performed by NEHRP organizations.

- Prediction effort has resulted in state laws regarding a prediction evaluation system, protection from liability for government officials acting on a prediction, and preparation of a state prediction response plan. Several local governments are preparing prediction response plans.

- The Southern California study[6] is a landmark compendium of valuable and useable earth science information. Similar efforts are needed to make new information available quickly.
- New standards for the design of highway structures and techniques to strengthen existing structures were developed from research sponsored by NSF and NBS. The latest revisions in the seismic building code used in all of the western states built upon the work behind the "NEHRP Provisions,"[7] and the report serves as a valuable commentary.
- The California Strong Motion Instrumentation Program, consisting of over four hundred installed recording devices, is made more effective by sharing the distribution of stations in a complementary fashion.
- A network of 600 sensitive seismographs allow accurate recording and location of earthquake and delination of active faults. State and local government officials and the news media rely on USGS scientists to interpret the meaning of increased seismic activity. State law and local land use policies now incorporate special standards for active faults and areas prone to ground failure and landsliding.
- Emergency planning and awareness efforts have been helped by the concern for earthquakes. FEMA has supported seminars and workshops that have drawn thousands of local and state government officials, engineers, geologists, hospital administrators, and so on. The BAREPP and SCEPP projects have stimulated a broad range of activities in their areas.
- Emergency planning in public and private schools has been helped by distribution of a FEMA-prepared guidebook to schools thoughout California.
- The program has helped develop a cadre of dedicated federal, state, and local government employees and private contractors which now provides a reliable source of expert advice, and an unrelenting lobby throughout the state for hazard reduction efforts.

Federal Leadership Needed

As valuable as these state and local government, private sector, and NEHRP accomplishments are, they are merely a start. There are a few jurisdictions with exemplary programs - and the hundreds with none. Many people know about earthquakes - but few have taken action to reduce earthquake hazards. Hundreds of thousands of businesses have not addressed earthquake risk.

NEHRP and the California programs have yet to reach a "critical mass" where a *majority* of local governments, businesses, and individuals undertake hazard reduction measures and sustain the effort as a permanent way of life. If government leadership and programs were eliminated, the effort would cease, and in a few years all our progress to date would be lost.

Now, when there is great receptiveness to hazard programs, is the time for the federal program to strengthen its hazard reduction efforts in conjunction with states and local governments. The federal government must provide leadership, money, and technical assistance to local governments. The federal program must accommodate this situation by providing increased assistance to local government programs.

In California, increased federal funding will save lives, protect the federal interests, and the economy. New information on fault locations, earthquake recurrance intervals and magnitudes, location of hazardous soil conditions, soil response, and engineering research on response of existing structures, techniques to strengthen such structures, and ground motion will quickly be used to reduce hazards.

California's Priorities and Programs

In 1985 Governor Deukmejian signed the California Earthquake Hazards Reduction Act of 1986, which established the goal of significantly reducing California's earthquake hazards by the end of the century. The initial five-year program has been prepared under the new law and published as *California at Risk: Reducing Earthquake Hazards 1987 - 1992.*[8] The five-year program provides California agencies with responsibilities for earthquake safety with a common foundation, and assures that their efforts are coordinated.

Congress should consider adopting this as the overall goal of the NEHRA.

California's five-year program is intended to:

- Establish priorities
- Provide common earthquake-safety objectives for all agencies and private companies
- Coordinate the work of responsible organizations
- Monitor progress in a systematic way
- Assure accountability in meeting objectives

The program also recognizes that a great deal still needs to be done, despite *ad hoc* efforts made over a sixty-year period to improve earthquake safety. The most important, but also the most costly and controversial earthquake problem is the hazard of existing unsafe structures. Although, as noted above, the state and a few local governments have recently taken some significant steps to address this problem, much remains to be done.

The program provides for a series of new initiatives to promote life safety. Its priorities stress initiatives dealing with existing development and emergency planning and response. New initiatives, intended to add to the existing statewide program, address existing and new development, emergency planning and response, postdisaster recovery, public information and education, and research. (A full description of new initiatives to be carried out during the current year are summarized in Appendix B.)

Although California has an outstanding record of accomplishment with coordinated multiagency earthquake safety programs, much remains to be done through federal-state cooperation in California. Reauthorization of NEHRA, providing adequate funds, and focusing on existing hazards and emergency response are of critical interest to California.

IMPORTANT ISSUES FACING THE NEHRA

Although the NEHRA has accomplished a great deal, there are certain shortcomings that should be addressed with the goal of improving the effectiveness of the act. If the federal government is truly interested in a national earthquake hazard reduction program, is it willing to commit the resources, and strengthen the leadership to make the program work in a focused, mission-oriented way? The committment of $65 million is not a strong statement of support.

Federal Leadership

Leadership has been an issue since the inception of the program. The 1980 amendments to the act did not empower the lead agency to set goals and priorities, or to see that they were being carried out. Furthermore, appropriations have never provided the resources needed for effective leadership. An original proposal was to establish an independent office to be responsible for the national earthquake hazards reduction program, and to establish an independent and permanent lead agency advisory committee.

At present NEHRP is fragmented, frustrating attempts to focus on specific goals and priorities, and implement the act's goal of a coordinated hazard reduction effort. The reauthorization process is the only meaningful opportunity for an overall look at the program.

A few examples of the fragmentation will serve to highlight the problem. The budget process is divided among four agencies, four different budget examiners at the Office of Management and Budget, and three different subcommittees of the House Appropriations Committee. There is no single line item in the President's budget for earthquake hazard reduction programs even though there is statutory authority for the program. The NEHRP five-year plan should be a guiding document, and each agency's budget should be in step with it, but they are not. The committee should consider amendments to assure that the earthquake hazard reduction program and its component parts are managed in an integrated manner.

The act provides broad multiple goals, all of which are important elements of a comprehensive earthquake hazard reduction program. The existence of a number of goals, tight fiscal constraints, and no strong centralized mechanism to guide and coordinate agency efforts and expenditures results in the resources being spread too thin. The lead agency must be given the authority to set specific measureable goals for the program, establish priorities for these goals, and assure that they are met.

At present there is no provision for meaningful accountability to the lead agency. Without an enforceable mechanism to carry out priorities, participating agencies need not follow. As a result, multiple approaches to the same problem, imbalances between user needs and federal services and products, competition, and lack of cooperation can make the program less effective. The act should be amended to provide for strong leadership and accountability. For example, accountability could require each agency to report annually to the lead agency its expenditures, along with an explanation of how the program meets the objectives set by the five-year plan. Program elements that fail to meet the plan goals and priorities would not be funded through the program.

Although the act presents NEHRP as a high priority program, its component parts are merely secondary elements of other programs. Appropriations for the earthquake programs are only small parts of each agency's budget. For example, FEMA's $5.313 million appropriation request is but 2.5 percent of the overall FEMA budget; the USGS appropriation request of $3.2 million is less than 10 percent of the USGS budget; the $0.5 million request is but a fraction of the NBS budget, and the $26.7 request is less than 2 percent of NSF's budget. In this situation one of two management attitudes may be present: The program may be regarded as an unimportant appendage to an agency's overall mission; or the agency may recognize the importance of the program to the nation, give it high priority, and whenever possible manage the other agency programs in a supportive manner. Unfortunately, an April 1986 list of FEMA priorities indicates that the earthquake hazards reduction program falls twelfth in a list of twenty of the agency's internal priorities. A similar situation may well exist at the other agencies, since the highest level government leaders show little public support. The Surgeon General's stance on smoking is well known, but where, or who, is his counterpart on earthquakes?

This situation is unacceptable. The earthquake hazard is so important that the director of each agency should give it high priority, and lend personal support and prestige to the program.

Earthquake programs and hazard-reduction priorities are too important to California and the nation to risk being lost among other competing demands and priorities. Although funds needed for lead agency responsibilities are small, and will remain so even at appropriate levels of funding, such an organization is essential to assure that the program is given strong, consistent support at the highest levels. A lead agency with this commitment must be found.

The situation in earthquake hazard reduction at the federal level is similar to that in California. Important earthquake programs constitute but a small portion of the overall responsibilities of departments responsible for emergency response, geological hazards, and structural engineering. The state responded by establishing a Seismic Safety Commission as an independent and single-minded body charged with making certain that earthquake safety is never overlooked.

A similar independent, permanent federal commission should be established to guide NEHRP. It should be given the authority, personnel, and financial resources to set goals and priorities, and see that they are being met, provide coordination, and assure that a consistent, focused national program is followed. The panel would be composed of state and local government and private sector professionals and other nonfederal government experts involved in reducing earthquake hazards. This body would be a mechanism to provide overall direction, stature, and visibility to the program.

A panel of this description could be independent of the other agencies, freeing them to conscentrate on carrying out their missions. The Office of Science and Technology Policy may be a candidate to establish such an organization.

Funding

The name of the act clearly spells out its intention: Earthquake hazard reduction. The Congress should take careful stock to see if this is occurring, and to decide what is needed to accomplish what the federal government began to do ten years ago. Hazard mitigation is primarily the responsibility of the private sector, and local and state governments, yet federal assistance to state and local governments to carry out politically sensitive and expensive hazard reduction programs, many of which must deal with retroactive building standards, is limited to two percent of the NEHRP program. Ironically, some of the program's greatest successes have come from helping the State of California nurture local government and private sector programs, yet federal funding for these programs remains inadequate, and in California it is decreasing.

The overall program is underfunded. The program is currently unable to support the level of activity needed in California. In fact, the program has never been funded at the level believed necessary in the eyes of national experts. The Newmark-Stever Report[9] made recommendations for research funding in earthquake engineering and seismology. These recommendations and the recommendations put forth by the Steinbrugge committee's[10] review of the federal 1983 five-year plan have never been met. Not only has funding for NEHRP been set at bare minimum levels, but the funding has remained essentially level for ten years while inflation has reduced its effectiveness by about one half. The gap between what the nation needs and what it gets continues to widen.

Federal earthquake hazard reduction programs in California are decreasing due to increased costs and shrinking budgets. Furthermore, recognizing that other states also have earthquake risks, federal agencies are spending their dollars increasingly on efforts to assist these states. Californians welcome efforts by other states to reduce earthquake hazards and to increase their emergency response capability and readiness, but are gravely concerned that the federal program is no longer able to meet the critical needs of the most seismically active states. Increased funding is necessary if the federal government is going to continue to contribute to reducing hazards in the states with the most at stake for the nation and the greatest proven ability to apply the results of the program.

Taking advantage of the momentum in California will require persistent efforts, a consistent program and more federal funding, not less. Faced with a reduction in funding, state and local preparedness planning, multihazard planning, research, and earthquake education and information transfer in California are not progressing as they could. The resistance to needed new programs at the state and local government levels in California is more financial than philosophical.

In spite of the limits placed on the federal budget, Congress should immediately restore funding to its before inflation 1977 level for the next fiscal year, and provide additional funding for increased application and the new leadership activities called for above. Because NEHRP funds are already spread too thin, new responsibilities called for in the amendments must be fully funded so that they do not detract from other necessary activities. Funding to FEMA for local and state government assistance should be increased threefold Funding for subsequent years should be determined by the new five-year plan and a careful review of the landmark Newmark-Stever and Steinbrugge reports mentioned above.

Federal Facilities, Operations, and Contracting

The lead agency must be given the legal and bureaucratic tools to see that each federal agencies carries out earthquake safety programs for their own factilities and operations, and through the programs they administer, according to common priorities. The federal government is the largest emplcyer in the nation and, as pointed out earlier, its presence in California is substantial. The federal government has responsibilities for protecting its own employees, facilities and operations, for recovery, for emergency response planning, and for research.

NEHRP could make an important contribution to national earthquake hazard reduction, and to earthquake safety in California, by adopting a program to strengthen those federally owned or operated facilities determined to be potentially hazardous. Emergency earthquake plans should be prepared for each federal facility in seismically active states. Federal employees should be trained to prepare for an earthquake at work and at home; when employees and their families are prepared, they will be more effective in carrying out emergency responsibilities. All major contractors and also suppliers should also reduce earthquake hazards. (Sporadic progress is being made in this area. The accomplishments of the Veterans Administration in strengthening hospitals nationwide is exemplary.)

Not only would a federal facilities program reduce hazards for a significant portion of the workforce, but it would also protect the federal government from avoidable losses and demonstrate to the community at large the importance of reducing hazards and the feasibility of risk reducing measures. Moreover, consultants, contractors, and planners trained while carrying out federal work would be better able to help local governments and private corporations.

This demonstration of leadership at the federal level would materially assist the earthquake hazard reduction effort in all seismically active regions and help establish this "critical mass" of programs that would be self-sustaining. This effort would be a tangible way for the federal government to help achieve California's goal to reduce statewide earthquake hazards significantly by the end of the century.

In mid-February 1987, FEMA forwarded a proposed Executive Order to the Office of Management and Budget that would require use of seismic codes in new construction and renovations of existing facilities. This Executive Order will be a good start in reducing earthquake hazards, but Congressional oversight is needed to assure a meaningful policy is enacted expeditiously.

Financing Hazard Reduction

Reducing hazards in buildings, public or private, costs money, and can affect the supply of housing, cause dislocation, and raise rents. Few local governments have the financial resources to strengthen weak buildings and establish an adequate response capability. California is moving ahead with a $800 million bond measure to strengthen state-owned buildings, and is also considering offering state income tax credits to owners who strengthen potentially hazardous private buildings. Incentives are also needed at the federal level. Although the subject of incentives is too broad for the reauthorization hearing, unless the federal government helps provide meaningful incentives to those who invest in the often unprofitable endeavor of strengthening hazardous buildings, significant improvements in damage and death figures will not occur.

Recent experience in California with programs to strengthen hazardous buildings has revealed that, ultimately, risk reduction involves such basic issues as housing, redevelopment, and economic development at the local, state, and federal levels. In 1985, FEMA published a report titled *An Action Plan For Reducing Earthquake Hazards Of Existing Buildings.*[11] The plan assigns tasks and funds to responsible agencies. Unfortunately, it appears that this plan has not been supported by NEHRP agencies. This is another indication of the need for strong leadership. Congress should inquire about its status, and issue a directive that it is to be carried out.

Congress should also recognize the economic realities of hazard reduction and direct agencies with grant and funding programs, and those who can provide other incentives, to see that their programs and resources are used to strengthen dangerous buildings.

Program Priorities

The federal program must concentrate its limited resources in ways to reduce hazards in developed areas in accordance with the goals of the act. This can best be accomplished by focusing effort on reducing hazards in existing structures, preparing plans and developing capability for an emergency response effort, and assuring that existing knowledge is put to use.

Hazard reduction and emergency response planning involves complex interactions between numerous individuals, ranging from research scientists and political decision makers at all levels of government to business leaders and private property owners. It involves research in a number of disciplines, legislation, education, professional practices, and government funding policies. These activities, organizations, and individuals must all be integrated to form a coordinated program. A coordinated program should have common priorities, and a balance among efforts.

A coordinated research and implementation strategy to deal with existing hazardous structures is needed. When research is directed towards real needs, and an implementation structure is in place, the results will be used. This is the reason why the Commission gave its support to a proposal to establish a research center focusing on hazardous structures. The Commission would have provided the assurance that the research results would have been translated into action and policy. Although the initial attempts to establish such a center were unsuccessful, there is still an urgent need for earthquake engineering research directed towards this high priority problem. Congress should find a way to assure that research directed towards the most critical seismic safety needs is funded in such a manner as to maximize its application.

The need for coordinated support for emergency management planning must be stressed. Preparing for earthquake emergency response in California results in a comprehensive emergency capability that can respond to most other natural and technological emergencies. A direct planning mechanism involving the federal government and local governments exists, and the new information is available, but FEMA's Emergency Management Assistance Program is directed to other issues and does not support the needed information transfer. Preparing the nation to respond to earthquake emergencies will strengthen the nation's overall emergency response capability.

New awareness of the nationwide threat of earthquakes has created a glaring need for increased technology transfer to decision makers, engineers, emergency response officials and others with front-line responsibility for earthquake safety. The demand is now nationwide further straining available resources. The gap between research accomplished and application of the results to reduce hazards is a major weakness of the program, and its getting worse. All of the agencies involved in the program have responsibilities for information transfer, but generally speaking these efforts are inadequate. For example, NSF and USGS support only small efforts to transfer their findings, and FEMA allocates less than $2 million of NEHRP funds to state and local earthquake preparedness activities. This level of effort is not enough, given the number and complex relationships of the organizations involved.

In California, little will be accomplished without the support of the officials of the nearly 500 local government bodies - mayors, city councils, Board of Supervisors, and their mangement staffs. The application of research results is often a political process, the persons involved are best reached through directed efforts and personal contact such as is provided by preparedness projects. Thus, increased funding for state and local preparedness planning, earthquake education, and information transfer is needed. Transfer of research results and new technology, and the application of this information, must be on the same priority level as advancing our understanding and knowledge.

Furthermore, federal programs that provide funding for local government infrastucture, housing, and emergency management planning, and those that regulate certain activities, must support hazard reduction measures. For example, recent cuts in HUD's Community Development Block Grant Program severly retard efforts to strengthen existing dangerous buildings, especially those located in the central districts of our older cities. Similarly, recent changes to the federal tax code provisions for investment tax credits reduce the availability of development funds for needed projects. An agressive effort is needed to identify and enact federal incentives such as grants, tax credits, loans, loan guarantees, and other assistance programs to encourage local governments and owners to carry out hazard reduction projects.

The Parkfield experiment remains a high priority project in California; the state believes the experiment is of such value that it contributed $1 million during 1986 to improve the monitoring instrumentation, and is preparing a response plan tailored to deal with the prediction. The results of this plan will be used to assist other agencies deal with the political and legal realities arising from future predictions in urbanized regions. But the experiment also serves as an example of the lack of coordination in the federal program. Even though the USGS and the state have decided to emphasize this program, FEMA has not provided any support for the effort to plan the response to a prediction.

Matching FEMA Funds

FEMA has informed the states that beginning FY 88 NEHRP funds must be matched fifty-fifty by nonfederal funds. The state share must be "hard," with cash. The State of California has been matching federal funds on a fifty-fifty basis since 1980 for the Southern California Earthquake Preparedness Project, and since 1984 for the Bay Area Regional Earthquake Preparedness Project. Beginning July 1, 1987, California's share will increase, making the match 60-40. Requiring matching funds for certain programs is a reasonable requirement, but Congress must recognize the critical importance of unmatched federal funds for certain "start-up" programs. For example, such efforts as determining the vunerability of areas to earthquake hazards and increasing public awareness are often more practicable if nonfederal matching funds are not initially required. The Commission used unmatched FEMA funds to conduct the Bay Area Earthquake Study which lead to the present jointly funded BAREPP.

It is ironic that FEMA, because of pressure from the Office of Management and Budget, must require matching funds for the assistance programs that apply the research results of the other elements of NEHRP so successfully. Although matching funds are not an issue to the State of California, it is of critical importance to fledgling programs in other states. If the emphasis is to be on implementing hazard reduction efforts, programs must encourage state and local participation. A hard requirement for matching funds will inhibit the success of the national program.

RECOMMENDATIONS

Federal Leadership Recommendations

- Adopt the goal to reduce nationwide earthquake hazards significantly by the end of the century.
- Form an independent, policy-level body to give overall guidance and oversight to the program.
- Require participating agencies to be accountable to the leadership organization.
- Combine appropriations for the program into a single line item in the President's budget to allow for integrated budgeting.
- Provide a mechanism to review the programs carried out by participating agencies to assure they are devoted to priority hazard reduction efforts.

Funding Recommendations

- Restore funding for the next fiscal year to the 1977 level before inflation.
- Provide adequate funding for new leadership activities.
- Increase funding for local and state government assistance.
- Determine future funding from the revised five-year plan and a careful review of the Newmark-Stever and Steinbrugge reports.

Program Priority Recommendations

The risk to life, property, and national security primarily involves hazards in areas already developed. NEHRP should reflect this fact by giving priority to programs that:

- Study active faults to determine paleohistoric earthquake return intervals and typical earthquake characteristics.
- Increase seismological and engineering research to determine ground motion criteria for the design of new buildings, and analysis existing buildings.
- Increase research on ways to identify existing buildings that are likely to be life-safety hazards during earthquake shaking.
- Develop engineering methods to reduce hazards from structural and nonstructural elements.
- Identify and map ground-failure hazards.

- Step up efforts to to apply knowledge that is available on earthquake hazards and reduction techniques.
- Improve the earthquake awareness of local and state governments, private companies, and the public.
- Aid in determining the vunerability of cities and regions to earthquake damage.
- Promote local government and private sector efforts to carry out hazard mitigation and emergency planning.
- Provide financial incentives to mitigate hazardous conditions.

Application of Research Recommendations

- Provide assurance that research is directed towards the most critical seismic safety needs.
- Give equal priority to the transfer of research results and new technology, and the application of new information, as is given to advancing our understanding and knowledge.
- Provide federal funds for planning emergency response to earthquake disasters.
- Initiate an effort to identify and enact federal incentives to encourage local governments and owners to carry out hazard reduction projects.

Facilities, Operations, and Contracting Recommendations

- The Office of Management and Budget should approve the Executive Order requiring agencies to apply seismic standards to new construciion and to strengthen federally owned facilities whose collapse would endanger life, inhibit the federal government's ability to respond effectively during an emergency, or inhibit the federal government's ability to carry out necessary programs in the aftermath of an earthquake.
- Require emergency response plans, and employee training at all federal facilities.
- Require all major contractors and suppliers whose ability to operate and provide services and material is considered critical to adopt hazard reduction and employee training programs.

Matching FEMA Funds Recommendations

- Allow the use of unmatched federal funds for determining the vunerability of areas to earthquake hazards and increasing public awareness.

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Appendix A

THE CALIFORNIA PROGRAM

California is the state that is most at risk from earthquake hazards, and has responded with a broad program. The state spends about $25 million per year (see Figure 1) on earthquake safety programs. The following summary of key programs will illustrate the scope and level of our existing effort.

Safety of Dams Program

The Safety of Dams Program was initiated after the Saint Francis Dam failure in 1927, although the failure was not caused by an earthquake. The program, carried out by the Department of Water Resources, Division of Safety of Dams, has provided an excellent basis for a dam earthquake safety program. After the 1971 San Fernando earthquake caused the near collapse of Lower Van Norman Dam, the state reviewed the earthquake safety of all existing dams, increased its standards, and stepped up efforts to inspect and review dams periodically. Several dams have been substantially strengthened, and some totally rebuilt.

Uniform Building Code

Prompted by the 1925 Santa Barbara earthquake, a committee of structural engineers, architects, and contractors worked for several years on earthquake design standards, and the International Conference of Building Officials incorporated lateral force code requirements in the Uniform Building Code, (UBC). Use of the UBC, however, was not required by the state at that time.

The Riley Act

After the 1933 Long Beach earthquake, the state enacted the Riley Act that mandated the use of minimum wind and earthquake forces in building design. Today, regulations adopted by the state in Title 24 of the California Administrative Code incorporate the UBC as a minimum standard. The Department of Housing and Community Development is the state agency responsible for enforcing the Riley Act. The principal intent of the building code is to protect life in a major earthquake, rather than control damage or guarantee continued use of the structure after an earthquake. In spite of the law, however, many local governments did not enforce seismic provisions until the 1950s.

The Field Act

Also after the 1933 earthquake, the state enacted the landmark Field Act that required public school buildings to meet special seismic safety requirements. Under the Field Act, all public school construction plans are prepared by a California architect or structural engineer. The plans are reviewed and constructionobserved by structural engineers and field representatives who work for the State Department of General Services, Office of State Architect. School boards are required to hire approved inspectors for detailed construction inspection for conformance with approved plans. This was the first instance of state preemption of municipal authority to regulate construction. Although public schools built subsequently have performed well in California earthquakes, there is serious concern about private schools, which are exempt from the Field Act standards and procedures. Concern has also been voiced about some of the public schools built decades ago in the early days of the Field Act, before its seismic standards were tightened on the basis of recent earthquake experience.

While existing private schools are not addressed in state law, a law enacted in 1986 requires special review of plans and construction of new private school structures similar to that required for essential services buildings (see below).

Special Studies Zone Act

After the 1971 San Fernando earthquake, the state enacted the Special Studies Zone Act (the Alquist-Priolo Act). It requires mapping of all active faults (faults with identifiable movement or surface rupture in the last 11,000 years), and calls for geologic studies if new development is proposed in identified active fault zones. The mapping is carried out by the Department of Conservation, Division of Mines and Geology. Local governments enforce the act by requiring geotechnical reports and approving, modifying, or denying building permits. Placement of structures in known active fault zones is thus carefully regulated, but California still has significant risks from fault rupture because:

1. Many buildings were built in active fault zones before the act was passed.

2. Faulting may occur in unmapped areas.

3. The law exempts dwellings with fewer than five units.

Bridge Strengthening Program

The collapse of several highway structures in the San Fernando earthquake of 1971 prompted the Department of Transportation to identify 1,300 bridges and overpasses statewide that needed seismic strengthening. Cable restrainers have been installed on nearly 1,200 of these structures to prevent them from collapsing. Since the program began, only one bridge has been damaged, and its restrainers prevented the bridge deck from suffering complete collapse.

Strong Motion Instrumentation Program

Recognizing that laboratory and shaking-table tests and mathematical studies, while extremely valuable, cannot fully or adequately predict the actual seismic performance of real structures, the State of California embarked on a program to install strong motion instruments in representative structures throughout the state. The Department of Conservation, Division of Mines and Geology, is responsible for installing and maintaining the instruments, reading the data, and analyzing and disseminating the results. The value of this program was demonstrated when records of the 1979 Imperial Valley earthquake led to changes in the UBC.

Hospital Seismic Safety Act

The collapse of the Veterans Hospital in the 1971 San Fernando earthquake took 44 lives, and Los Angeles County's newly opened Olive View Hospital was damaged beyond repair. This experience prompted the state to adopt the Hospital Seismic Safety Act, once again preempting what had been a municipal responsibility. This law requires all new hospitals to meet state-imposed standards to ensure that they not only survive but remain operational after an earthquake. Plans for new hospitals are subjected to rigorous independent review, and construction is inspected by the Office of Statewide Health Planning and Development and the Office of State Architect. This law is not retroactive, however, and at present only seven percent of the hospitals in California meet the standard. A major earthquake that struck a large urban area today would probably make between one-third and one-half of the hospital beds unusable.

Land Use Planning Law Amendment

The basic Land Use Planning Law was amended in 1972 to require that all municipalities include a seismic safety element in their land use plans, and to consider the information in making land use decisions. Although seismic safety elements are mandated, no standards or enforcement procedures have been provided to assure their quality.

School Emergency Planning

A 1984 state law requires all schools to prepare emergency plans and to practice using them. The Seismic Safety Commission has provided every school in the state with a copy of a how-to guidebook on developing school earthquake safety programs prepared by the Federal Emergency Management Agency.

Essential Services Buildings Act

A 1985 state law requires that all new police and fire stations, emergency operations centers, and communications facilities be built so as to remain operational during and after an earthquake. Design drawings are subject to independent review and special inspection by the local government. In addition, the designer of record is required to visit the job site during construction.

Unreinforced Masonry Building Program

A law passed after the 1985 Mexico City earthquake mandated that municipalities identify all unreinforced masonry buildings built before codes were adopted, and adopt programs to address the hazard. This must be done by January 1, 1990. It has been estimated that approximately 40,000 to 50,000 of these structures are still in use, and studies indicate that nearly nine out of ten of them would probably suffer life-threatening failures when shaken by a damaging earthquake. Only seven California municipalities – Los Angeles, Long Beach, Santa Rosa, Santa Ana, Santa Monica, Palo Alto, and Sebastopol – had acted prior to passage of this mandate to adopt hazard-reduction programs

Earthquake Preparedness Campaign

Acting primarily through the Office of Emergency Services, the state conducts an Earthquake Preparedness Campaign, highlighted by an annual Earthquake Week. Public awareness of earthquakes and understanding of their effects are critical to reducing hazards and improving response. These efforts are intended to strengthen public support for earthquake safety measures, and to drive home to people the realization that they, as individuals, should and can take steps to improve their own and their families' safety, so that they will be more strongly motivated to act.

Emergency Response Plans

Being on the front line, cities and counties are typically the first jurisdictions to respond after an earthquake. They are encouraged to have local emergency response plans that are certified by the state Office of Emergency Services. When an emergency requires resources that are beyond its capability, an individual local government can request help from neighboring jurisdictions through mutual aid agreements. When an emergency exceeds *regional* response capabilities, the state mobilizes support. The Office of Emergency Services has prepared a new earthquake emergency response plan for southern California, an area with 180 municipalities and 12,000,000 people. The new plan was adopted in concept by the Governor's Emergency Council on February 26, 1987.

State Emergency Operations Center

A new state emergency response center for southern California is being designed for use as an operations center in responding to future earthquakes.

Dam Inundation Mapping Program

After the near collapse of Lower Van Norman Dam in the 1971 San Fernando earthquake, owners of dams throughout the state were required to map areas that would be flooded in case of dam failures. Local municipalities can use these maps in making plans to evacuate populations exposed to possible inundation.

Parkfield California Earthquake Plan

Scientists are not yet generally able to predict earthquakes with any degree of precision, but there is a unique situation in Parkfield on the San Andreas fault in central California. The unusual regularity of past earthquakes there leads experts to expect a moderate earthquake in January 1986. Scientists have installed sensitive scientific instruments in an attempt to detect precursors to the expected earthquake, and if warranted by the evidence a short-term prediction will be issued. In view of this possibility, a short-term prediction response plan is being prepared, the first ever in California.

The California Earthquake Education Project

The California Earthquake Education Project (CALEEP) was established in 1981 to develop educational materials in earthquake science and hazard reduction and response for grades 4-8. Now that tested materials are available, efforts are being directed at teachers to help them develop effective ways to use the materials. Ways are also being sought to incorporate the materials into the curricula of all primary schools in the state.

Earthquake Preparedness Projects

The Southern California Earthquake Preparedness Project (SCEPP) and the Bay Area Regional Earthquake Preparedness Project (BAREPP) provide technical assistance to local governments and business firms on hazard reduction and emergency preparations, and have developed earthquake preparedness planning materials to assist cities, counties, businesses, and community organizations. Both projects are guided by policy advisory boards consisting of community leaders and experts. The projects host conferences and workshops, and work with the media to promote awareness, mitigate hazards, and plan for emergency response.

Appendix B

FUTURE PRIORITIES AND PROGRAMS

California's five-year program, *California At Risk: Reducing Earthquake Hazards 1987-1992,* provides a number of new initiatives needed to reduce statewide earthquake hazards significantly by the end of this century. The following summary of new initiatives are to be carried out in California during the 1987 calender year.

Existing Development

Dealing with hazardous existing developments is expensive, but this is what will save the most lives in future earthquakes. Accordingly, California must begin working on these initiatives now. The following new initiatives are proposed for Existing Development:

- *Buildings constructed of unreinforced masonry* - Under legislation signed into law in August 1986, cities and counties in Seismic Zone 4, the most active seismic area, must inventory unreinforced masonry buildings and adopt hazardous-building mitigation programs to strengthen, raze, or otherwise reduce hazards associated with occupancy of such buildings.

- *Pre-Hospital Act structures* - Complete a survey of hospitals constructed prior to 1973, and evaluate the results to determine the probable loss of operational capacity following an earthquake. Prepare recommendations for measures to strengthen such buildings, and develop a schedule to reduce these hazards.

- *Mobile Homes* - Implement recently enacted legislation to reduce the vulnerability of mobile and manufactured homes through the use of earthquake-resistant foundation systems.

- *Early public school buildings* - Survey construction documents of public schools designed and built in the early years of the Field Act to determine whether any significant life-safety hazards exist. Identify those facilities in need of strengthening and prepare a program to reduce the identified hazards.

- *State-owned buildings* - Seek legislation and voter approval for $800 million in general obligation bonds to strengthen or remove hazardous state-owned buildings (including those owned by the University of California and the California State University system).

- *Incentives for hazard reduction* - Enact legislation offering incentives, such as state income tax credits, to property owners to encourage them to strengthen hazardous facilities.

- *Building codes* - Change existing building codes to require seismic strengthening of structures when repaired or remodeled for other purposes.

Emergency Planning And Response

Emergency response also has a high priority. Moreover, improving the state's emergency response capability is much less costly than renovating existing structures. The following new initiatives are proposed for Emergency Planning and Response:

- *Emergency Planning* - The state Office of Emergency Services (OES) should complete and adopt the Southern California Earthquake Response Plan, and develop a concept of operations for statewide emergency response. A similar plan should be adopted for the San Francisco Bay Area.

- *Emergency Operation Centers* - The state should establish and maintain a permanent Emergency Operations Center in southern California for managing regional disasters. This center should be capable of operating after a large-magnitude earthquake. The state also should evaluate the need for a similar operations center in northern California. All city and county governments should have local emergency operations centers. It is crucial that local centers be capable of surviving and functioning effectively after a large-magnitude earthquake.

- *Short-Term Earthquake Prediction Response Plan* - The state should develop a Short-Term Earthquake Prediction Response Plan to provide state agencies with specific response actions, and to provide local jurisdictions with standard and consistent guidance on recommended local response actions in the event of a short-term earthquake prediction. Experience gained from the Parkfield Project should be evaluated for lessons in dealing with short-term predictions.

- *Emergency Management Systems* - OES should develop and adopt a standard computer-based emergency management system to facilitate the statewide coordination of emergency personnel and equipment, and assist with state direction and control functions during regional disasters.

- *Communications* - The state should develop and install communications system capable of surviving and operating effectively immediately after an earthquake and linking state agencies with each other, with the state coordination centers, and with designated local government facilities.

- *Urban Heavy Rescue* - OES should develop a search-and-heavy-rescue training program with ready access to specialized equipment for removing people from collapsed buildings. Plans should also be developed for integrating rescue and medical operations.

Future Development

California cannot afford to construct new buildings in hazardous areas where hazard mitigation is not practicable, and where the effect of earthquakes on structures is likely to endanger lives. New initiatives proposed for new development include the following:

- *New private schools* - Implement legislation signed into law in August 1986, requiring more careful checking of plans for private schools and more careful observation of their construction.

- *Local general plan review* - Enact legislation requiring local governments to review the seismic portions of local general plans periodically, so they can be updated with new information on seismic hazards, and appropriate measures taken.

- *Subdivision hazard review* - Require the evaluation of proposed new subdivisions for onsite hazards, as well as for offsite hazards — e.g., upstream dams — unless the requirement is specifically waived by the responsible local jurisdiction. Local governments should assure careful evaluation of any proposed development prior to approving any plans to locate a subdivision where there is a significant potential for unusual seismic hazards.

Recovery

In California little has been done to plan for post-earthquake recovery. Our worst-case loss estimates forecast about $50 billion in physical damage from a major earthquake in a metropolitan area. We are learning from Mexico City's experience that economic and social disruption will be of long duration, human and material resources will be in short supply, and government at all levels will face politically difficult choices. The program calls for the following new initiatives for post-earthquake recovery:

- *Local reconstruction authorities* - Legislation enacted authorizing local governments to create local reconstruction authorities and preparation of a model recovery plan should be carried out. The model plan should include the authorities and procedures for the orderly transition from emergency disaster response operations to short-range and long-range recovery efforts. Local jurisdictions should be encouraged to develop recovery plans and ordinances.

- *Review earthquake insurance* - Legislation should require the state Department of Insurance to conduct a comprehensive review of the insurance industry's earthquake-insurance offerings and of the public's acceptance, along with an examination of other issues relating to the scope of coverage and the probable contribution of insurance benefits to earthquake recovery.

- *Effects on state government* - The state should assess the consequences of a major earthquake on California state government, including revenue losses, increased demand for state services, unemployment costs, and losses of state property. Such an assessment will provide the basis for mitigation and recovery policymaking and planning.

- *Effects on the state's economy* - The state should assess the impact of a major earthquake on the state's economy, considering the vulnerability of the financial system and of particular industries, businesses, and utilities.

Education And Public Information

Educational efforts are needed to improve public understanding of earthquakes and of the value of hazard-reduction measures, as well as of the need for emergency preparedness measures. The program proposes the following new education and public information initiatives:

- *Earthquake preparedness campaign* - The state should provide permanent funding to the Office of Emergency Services to continue the earthquake preparedness campaign, and work with the media and the private sector to develop and broadcast earthquake preparedness public service announcements and distribute educational materials.

- *Earthquake science and preparedness curricula* - The Seismic Safety Commission should determine whether the California Earthquake Education Project (CALEEP) should be extended, and what role it should play in earthquake curriculum development and dissemination. The Commission should encourage the state Department of Education, CALEEP, and others to incorporate earthquake education into elementary, junior high (middle), and high school classes statewide.

- *School preparedness* - The Seismic Safety Commission should work to strengthen legislation requiring public and private school earthquake safety plans, including a requirement that every two years public schools file with their districts current earthquake safety plans that include the names of the school safety officers. A Safety Officer should be established in the state Department of Education.

- *Regional projects* - The Southern California and Bay Area Regional Earthquake Preparedness Projects will continue their mission of reducing earthquake hazards and preparing for emergency response and recovery in their respective areas until June 30, 1990. In consultation with the Office of Emergency Services and other affected agencies, the Seismic Safety Commission should determine whether similar projects should be established for other seismically active areas such as San Diego, Santa Barbara, or the Central Valley.

Research

We need to learn more about the causes and effects of earthquakes; the responses of structures, sites and materials; and the economic, legal, social, psychological, and other consequences. Research on such matters is a long-term investment in the future, and the program proposes the following new research initiatives:

- *The "California Center for Earthquake Engineering,"* authorized by legislation enacted in July 1986, should be established with matching funds from the National Science Foundation, or other sources.
- *Earthquake Early Warning System* - Recently enacted legislation requires the Department of Conservation to evaluate the feasibility of an early warning system for earthquakes. This study should be completed.
- *Strong Motion Program* - Legislative or administrative action should increase funding for the Strong Instrumentation Program, whose efforts need to be increased so that the highest priority typical structures will be instrumented by the end of the century.
- *"Five-Year Research Plan"* - The Seismic Safety Commission should establish research priorities based upon California's seismic safety needs and, in cooperation with appropriate state agencies, develop a comprehensive five-year research plan and strategy for carrying it out.

Appendix C

LOCAL GOVERNMENT EARTHQUAKE SAFETY PROGRAMS

- The City of Los Angeles has enacted an ordinance requiring owners of unreinforced masonry buildings to strengthen their buildings. It will cost property owners nearly $1 billion to comply.

- The City of Los Angeles also has well developed hazard reduction, emergency planning, prediction planning, and employee training programs.

- Los Angeles County is upgrading its emergency communication system so that it will operate after an earthquake, and is strengthening six firehouses that were found structurally deficient.

- Orange County recently committed $3.1 million to carry out the second phase of a well planned hazard reduction program.

- San Bernandino County has embarked on an ambitious plan to construct the new Eagle Emergency Operations and Training Center, which will be capable of functioning after an earthquake.

- All the cities in Santa Barbara recently signed a joint powers agreement to establish an emergency services organization.

- In 1986, the City of San Francisco voted overwhelmingly (89% in favor) of a $46 million bond measure to strengthen its post earthquake firefighting capability and to finance construction of a new emergency operations center.

- The City of San Francisco recently completed an inventory of all unreinforced masonry buildings, and has notified the owners. Work continues on an ordinance to require strengthening.

- The City of Oakland recently recreated an Office of Emergency Services in the City Manager's office after serveral years of not having such an activity.

- The City of Santa Rosa has identified and strengthened all of its uninreforced masonry buildings.

- The City of San Jose is preparing a long term master plan to reduce hazards and prepare for response to an earthquake.

- The San Diego County Board of Supervisors has adopted a comprehensive policy and established an Earthquake Preparedness Committee.

- The cities of South Pasadena and Monterey Park have recently adopted ordinances requiring owners to strengthen unreinforced masonry buildings.

- The City of Palo Alto has identified all buildings considered potentially hazardous during an earthquake, and adopted an ordinance requiring notification of owners and posting of unreinforced masonry buildings.

- All jurisdictions in Seismic Zone 4, over four hundred cities and counties, are required to inventory unreinforced masonry buildings and adopt mitigation programs by 1990.

Appendix D

PRIVATE SECTOR EARTHQUAKE SAFETY PROJECTS

- California Banker's Clearinghouse, consisting of the Federal Reserve Bank and the state's largest banks (Bank of America, Wells Fargo, First Interstate, Security Pacific), has established a system to reestablish operations after an earthquake, created a radio network to link the banks within a region in case an earthquake destroys normal communication capabilities, entered into standby contracts to transport employees and records to remote processing centers, strengthened computer systems to improve their ability to resist earthquake forces, and provided research money to supplement NSF funding.

- Pacific Bell, Continental Telephone, GTE, AT&T, MCI, and other communications companies voluntarily joined to prepare an emergency response plan including liaison with state and local government emergency officials, provision of emergency telephone service, and a priority system for restoring normal service. These companies have invested several million dollars installing bracing and other hazard mitigation measures.

- Pacific Gas and Electric has prepared disaster plans for each installation, stored emergency response equipment and food, trained employees to undertake leadership roles in disaster situations, and conducted a major training program for employee safety in the workplace and at home. It is believed that employees will be far more effective in an emergency if they are confident that their families are safe.

- The San Francisco Symphony spent an extra $8 million to provide for increased earthquake safety in the construction of their new symphony hall, adopted emergency procedures, and routinely trains ushers to respond properly to a damaging earthquake.

- Chevron is preparing a corporation wide disaster plan focusing on earthquakes.

- IBM, recognizing its vulnerability to earthquakes in the San Jose region, spent about $25 million improving the earthquake safety of two of its buildings during the last six years.

- Hewlett-Packard is carrying out earthquake hazard reduction measures at its Palo Alto facility to strengthen its mainframe computer facilities.

- In Southern California, the Business-Industry Committee for Earthquake Preparedness (BICEP) has provided a forum for businesses to promote hazard mitigation and preparedness.

- The Industrial Council of Santa Clara-San Mateo Counties, a consortium of high technology businesses formed to develop its own earthquake response capability, provides training for members and operates its own emergency response vehicle.

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Mr. Tobin is the Executive Director of the Seismic Safety Commission. He is a graduate of the University of California at Berkeley and holds a Master of Science degree in Civil Engineering. He is a registered professional engineer. Prior to this appointment, Mr. Tobin was manager of the California Coastal Commission's Energy and Coastal Resources Division. Mr. Tobin has been involved in earthquake safety for over 20 years. He has participated in the seismic review and siting studies for dams, power plants, and LNG terminals and port facilities and has conducted siting studies for electrical generating plants, port, and LNG facilities.

Mr. Tobin is active in the American Society of Civil Engineers, and is a member of the Earthquake Engineering Research Institute. He has held elected office as a director of the Almonte Sanitary District in Mill Valley and is past president of the Sewerage Agency of southern Marin. He is married and has two children.

Mr. **Walgren**. Thank you very much, Mr. Tobin. That is a comprehensive statement for the record as well and one that we can take a lot of guidance from and we appreciate it.

Let's turn then to Dr. Ketter.

Mr. **Ketter**. Mr. Chairman, members of the subcommittee, thank you for giving the National Center for Earthquake Engineering Research the opportunity to provide testimony on the reauthorization of the National Earthquake Hazards Reduction Program. This opportunity is especially important at this particular time because of the newness of our program and our desire to substantially upgrade the state of the art of the basic knowledge, engineering practice and implementation of seismic hazard mitigation procedures in order to minimize the loss of property and human lives and the disruption of all facets of human activities resulting from severe earthquakes.

In August of 1986, the National Science Foundation established at the State University of New York at Buffalo a National Center for Earthquake Engineering Research. The Center was proposed by a consortium of institutions located in and around New York State. It is being funded initially by the National Science Foundation with matching funds from New York State and other sources. Future additional matching will be provided from State governments, New York and others, academic institutions, public benefit corporations, other governments and the private sector.

The consortium institutions include City College of New York, Columbia University, Cornell University, Lamont-Doherty Geological Observatory, LeHigh University, Princeton University, Rensselaer Polytechnic Institute and State University of New York at Buffalo. Researchers from other institutions, industry and practicing engineering firms throughout the country also are involved.

The Center brings together outstanding technical institutions and professionals with diversity of expertise in such areas as structural dynamics, artificial intelligence, seismotechtonics and information science; with superior technical facilities such as large and small-scale seismic simulators and materials testing equipment; super computers and computer graphic systems; strong motion-measuring devices and a wide range of digital and analog support systems.

The first year of operation of the Center is underway with a management structure in place. This work is guided by a director, an executive committee whose members are the principal investigators, and a nationwide oversight committee. A scientific advisory committee of pre-eminent experts in related disciplines currently is being organized.

For the first year beginning in September of 1986, the National Science Foundation provided $5 million with $5 million matching funds provided by the State of New York. It should be noted, however, that because of the level of the NSF funding, the actual total matching level, counting additional contributions from consortium institutions, industrial sponsors and others, is approximately $8.7 million.

The goal of the Center is to coordinate a team effort in the study of earthquake engineering. Current activities are directed towards: (a) developing an integrated approach to earthquake engineering research focused on systems aspects of structures and life lines; (b) active participation from industry, consulting firms and governmental agencies; (c) establishing an information center which will provide a wide range of services for users from industry, government and academic institutions; (d) developing a broadly-based educational program in earthquake engineering; and (3) planning workshops and conferences as forums for exchange of ideas and information among workers and researchers in earthquake engineering.

Initial research application emphasis is directed towards mitigation of the earthquake hazard in the eastern United States.

The first year plans of the Center were developed in accordance with these major objectives. They are the result of intensive discussion and planning on the part of the principal investigators with significant input from members of all participating institutions.

The first year is intended to establish a research base on which future efforts will be built and is designed to place the Center in a position to take a leadership role nationally and internationally in earthquake engineering research within the next five years. It consists of the following major programs:

Program One, seismic hazard assessment in the eastern United States.

Program Two, ground motion, soil and soil-structure interaction.

Program Three, Seismic performance, risk and reliability.

Program Four, innovative computing and expert systems.

Program Five, international cooperation for cooperative research.

In excess of 80 faculty members, scientists and engineers are engaged in these endeavors. Teams of researchers were formed to mount coordinated research efforts to define short-term and long-term goals and to formulate research plans.

The bulk of this first-year program is being carried out by members of the participating institutions; however, it is recognized that interactions with others are a vital component of the Center's plan. Efforts in this direction have been initiated, and this year's activities include a limited but significant participation from industry, consulting firms and other agencies.

The Center's contribution to all international cooperative projects under Program Five represents but a small portion of that program's cost. The research work being performed by investigators from participating countries is almost entirely supported by their home agencies, governments and/or institutions.

Education and technology transfer are important components of the mission of the Center. Current activities in this direction include the following:

Program Six (of our overall programs), workshops.

Program Seven, national and international conferences.

Both of these serve as forums for exchange of ideas and information among researchers and practitioners.

In addition, a comprehensive information service center is being established. This is a permanent facility which will provide a broad range of services for the staff of the Center, and also for the community, industry and the research interests throughout the country.

In closing, there are a number of conceptual and technical issues that remain and must be addressed and emphasized more for the ultimate purpose of earthquake hazard mitigation. The National Center for Earthquake Engineering Research is committed to an integrated, a systematic, a team effort approach to solving these problems. At the same time, it is understood that mitigation requires the cooperation, assistance and efforts of many—researchers, teachers, practicing engineers, industry and community leaders, federal, state and regional government officials and so on.

I thank you for the opportunity to give this brief overview.

[The prepared statement of Dr. Ketter follows:]

National Center for Earthquake Engineering Research
State University of New York at Buffalo

STATEMENT OF

DR. ROBERT L. KETTER, DIRECTOR

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

MARCH 10, 1987

Engineering West, Buffalo, New York 14260 Tel: (716) 636-3001

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE

THANK YOU FOR GIVING THE NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH THE OPPORTUNITY TO PROVIDE TESTIMONY ON THE REAUTHORIZATION OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM. THIS OPPORTUNITY IS ESPECIALLY IMPORTANT AT THIS PARTICULAR TIME, BECAUSE OF THE NEWNESS OF OUR PROGRAM, AND OUR DESIRE TO "SUBSTANTIALLY UPGRADE THE STATE-OF-THE-ART OF THE BASIC KNOWLEDGE, ENGINEERING PRACTICE AND IMPLEMENTATION OF SEISMIC HAZARD MITIGATION PROCEDURES IN ORDER TO MINIMIZE THE LOSS OF PROPERTY AND HUMAN LIVES AND THE DISRUPTION OF ALL FACETS OF HUMAN ACTIVITIES RESULTING FROM SEVERE EARTHQUAKES."

IN AUGUST OF 1986 THE NATIONAL SCIENCE FOUNDATION ESTABLISHED AT THE STATE UNIVERSITY OF NEW YORK AT BUFFALO A NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH (NCEER). THE CENTER WAS PROPOSED BY A CONSORTIUM OF INSTITUTIONS LOCATED IN AND AROUND NEW YORK STATE. IT IS BEING FUNDED INITIALLY BY THE NSF WITH MATCHING FUNDS FROM NEW YORK STATE AND OTHER SOURCES. FUTURE ADDITIONAL MATCHING WILL BE PROVIDED FROM STATE GOVERNMENTS, ACADEMIC INSTITUTIONS, PUBLIC BENEFIT CORPORATIONS, OTHER GOVERNMENTS AND THE PRIVATE SECTOR.

THE CONSORTIUM INSTITUTIONS INCLUDE: CITY COLLEGE OF NEW YORK, COLUMBIA UNIVERSITY, CORNELL UNIVERSITY, LAMONT-DOHERTY GEOLOGICAL OBSERVATORY, LEHIGH UNIVERSITY, PRINCETON UNIVERSITY, RENSSELAER POLYTECHNIC INSTITUTE, AND STATE UNIVERSITY OF NEW YORK AT BUFFALO.

RESEARCHERS AT OTHER INSTITUTIONS, INDUSTRY, AND PRACTICING ENGINEERING FIRMS THROUGHOUT THE COUNTRY ALSO ARE INVOLVED.

THE CENTER BRINGS TOGETHER OUTSTANDING TECHNICAL INSTITUTIONS AND PROFESSIONALS WITH DIVERSITY OF EXPERTISE IN SUCH AREAS AS STRUCTURAL DYNAMICS, ARTIFICIAL INTELLIGENCE, SEISMOTECTONICS AND INFORMATION SCIENCE; WITH SUPERIOR TECHNICAL FACILITIES SUCH AS LARGE AND SMALL SCALE SEISMIC SIMULATORS AND MATERIALS TESTING EQUIPMENT, SUPER COMPUTER AND COMPUTER GRAPHIC SYSTEMS, STRONG MOTION MEASURING DEVICES, AND A WIDE RANGE OF DIGITAL AND ANALOG SUPPORT SYSTEMS.

THE FIRST YEAR OF OPERATION OF THE CENTER IS UNDERWAY WITH A MANAGEMENT STRUCTURE IN PLACE. THIS WORK IS GUIDED BY A DIRECTOR, AN EXECUTIVE COMMITTEE WHOSE MEMBERS ARE THE PRINCIPAL INVESTIGATORS, AND A NATION-WIDE OVERSIGHT COMMITTEE. A SCIENTIFIC ADVISORY COMMITTEE OF PREEMINENT EXPERTS IN RELATED DISCIPLINES CURRENTLY IS BEING ORGANIZED.

FOR THE FIRST YEAR BEGINNING SEPTEMBER 1, 1986, THE NATIONAL SCIENCE FOUNDATION PROVIDED $5 MILLION WITH $5 MILLION MATCHING FUNDS PROVIDED BY THE STATE OF NEW YORK. IT SHOULD BE NOTED, HOWEVER, THAT THE ACTUAL TOTAL MATCHING LEVEL, COUNTING ADDITIONAL CONTRIBUTIONS FROM CONSORTIUM INSTITUTIONS, INDUSTRIAL SPONSORS AND OTHERS, IS APPROXIMATELY $8.7 MILLION.

THE GOAL OF NCEER IS TO COORDINATE A TEAM EFFORT IN THE STUDY OF EARTHQUAKE ENGINEERING. CURRENT ACTIVITIES ARE DIRECTED TOWARD:

a) DEVELOPING AN INTEGRATED APPROACH TO EARTHQUAKE ENGINEERING RESEARCH, FOCUSED ON SYSTEMS ASPECTS OF STRUCTURES AND LIFELINES,

b) ACTIVE PARTICIPATION FROM INDUSTRY, CONSULTING FIRMS AND GOVERNMENT AGENCIES,

c) ESTABLISHING AN INFORMATION CENTER, WHICH WILL PROVIDE A WIDE RANGE OF SERVICES FOR USERS FROM INDUSTRY, GOVERNMENT, AND ACADEMIC INSTITUTIONS,

d) DEVELOPING A BROADLY BASED EDUCATIONAL PROGRAM IN EARTHQUAKE ENGINEERING, AND

e) PLANNING WORKSHOPS AND CONFERENCES AS FORUMS FOR EXCHANGE OF IDEAS AND INFORMATION AMONG WORKERS AND RESEARCHERS IN EARTHQUAKE ENGINEERING.

INITIAL RESEARCH APPLICATION EMPHASIS IS DIRECTED TOWARD MITIGATION OF THE EARTHQUAKE HAZARD IN THE EASTERN UNITED STATES.

THE FIRST YEAR PLANS OF THE CENTER WERE DEVELOPED IN ACCORDANCE WITH THESE MAJOR OBJECTIVES. THEY ARE THE RESULT OF INTENSIVE DISCUSSION AND PLANNING ON THE PART OF THE PRINCIPAL INVESTIGATORS WITH SIGNIFICANT INPUT FROM MEMBERS OF ALL PARTICIPATING INSTITUTIONS.

THE FIRST YEAR IS INTENDED TO ESTABLISH A RESEARCH BASE UPON WHICH FUTURE EFFORTS WILL BE BUILT, AND IS DESIGNED TO PLACE NCEER IN A POSITION TO TAKE A LEADERSHIP ROLE NATIONALLY AND INTERNATIONALLY IN EARTHQUAKE ENGINEERING RESEARCH WITHIN THE NEXT FIVE YEARS. IT CONSISTS OF THE FOLLOWING MAJOR PROGRAMS:

PROGRAM 1: SEISMIC HAZARD ASSESSMENT IN THE EASTERN UNITED STATES
PROGRAM 2: GROUND MOTION, SOIL AND SOIL-STRUCTURE INTERACTION
PROGRAM 3: SEISMIC PERFORMANCE, RISK AND RELIABILITY
PROGRAM 4: INNOVATIVE COMPUTING AND EXPERT SYSTEMS
PROGRAM 5: INTERNATIONAL COOPERATIVE RESEARCH

IN EXCESS OF 80 FACULTY MEMBERS, SCIENTISTS AND ENGINEERS ARE ENGAGED IN THESE ENDEAVORS. TEAMS OF RESEARCHERS WERE FORMED TO MOUNT COORDINATED RESEARCH EFFORTS, TO DEFINE SHORT-TERM AND LONG-TERM GOALS AND TO FORMULATE RESEARCH PLANS.

THE BULK OF THIS FIRST-YEAR PROGRAM IS BEING CARRIED OUT BY MEMBERS OF THE PARTICIPATING INSTITUTIONS. HOWEVER, IT IS RECOGNIZED THAT INTERACTIONS WITH OTHERS ARE A VITAL COMPONENT OF THE CENTER'S PLAN. EFFORTS IN THIS DIRECTION HAVE BEEN INITIATED, AND THIS YEAR'S ACTIVITIES INCLUDE A LIMITED, BUT SIGNIFICANT, PARTICIPATION FROM INDUSTRY, CONSULTING FIRMS, AND OTHER AGENCIES.

THE CENTER'S CONTRIBUTIONS TO ALL INTERNATIONAL COOPERATIVE RESEARCH PROJECTS UNDER PROGRAM 5 REPRESENT BUT A SMALL PORTION OF THAT PROGRAM'S COST. THE RESEARCH WORK BEING PERFORMED BY INVESTIGATORS FROM PARTICIPATING COUNTRIES IS ALMOST ENTIRELY SUPPORTED BY THEIR HOME AGENCIES, GOVERNMENTS AND/OR INSTITUTIONS.

EDUCATION AND TECHNOLOGY TRANSFER ARE IMPORTANT COMPONENTS OF THE MISSION OF THE CENTER. CURRENT ACTIVITIES IN THIS DIRECTION INCLUDE THE FOLLOWING:

PROGRAM 6: WORKSHOPS
PROGRAM 7: NATIONAL AND INTERNATIONAL CONFERENCES

BOTH OF THESE SERVE AS FORUMS FOR EXCHANGE OF IDEAS AND INFORMATION AMONG RESEARCHERS AND PRACTITIONERS.

IN ADDITION, A COMPREHENSIVE INFORMATION SERVICE CENTER IS BEING ESTABLISHED. THIS IS A PERMANENT FACILITY WHICH WILL PROVIDE A BROAD RANGE OF SERVICES FOR THE STAFF OF THE CENTER, AND ALSO FOR THE COMMUNITY, INDUSTRY, AND THE RESEARCH INTERESTS THROUGHOUT THE COUNTRY.

IN CLOSING: THERE ARE A NUMBER OF CONCEPTUAL AND TECHNICAL ISSUES THAT REMAIN AND MUST BE ADDRESSED AND EMPHASIZED MORE FOR THE ULTIMATE PURPOSE OF EARTHQUAKE HAZARD MITIGATION. THE NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH IS COMMITTED TO AN INTEGRATED, SYSTEMATIC, TEAM EFFORT APPROACH TO SOLVING THESE PROBLEMS. AT THE

SAME TIME, IT IS UNDERSTOOD THAT MITIGATION REQUIRES THE COOPERATION, ASSISTANCE AND EFFORTS OF MANY - RESEARCHERS, TEACHERS, PRACTICING ENGINEERS, INDUSTRY AND COMMUNITY LEADERS, FEDERAL, STATE AND REGIONAL GOVERNMENT OFFICIALS, AND SO ON.

I THANK YOU FOR THE OPPORTUNITY TO GIVE THIS BRIEF OVERVIEW OF THE ROLE AND SCOPE OF NCEER IN THE EARTHQUAKE HAZARDS MITIGATION PROGRAM OF THE NSF.

Robert L. Ketter, Director of the National Center for Earthquake Engineering Research, and Leading Professor of Engineering and Applied Sciences at State University of New York at Buffalo, earned his Bachelor's degree from the University of Missouri in 1950. His M.S. degree (1952) and Ph.D. degree (1956) were warded by Lehigh University. He also has received the following honorary degrees: D.Sc. from Kyungpook University, 1973, D.Eng. from Lehigh University in 1981. In 1986 he was made an Honorary Professor of Engineering of Beijing Polytechnic University and an Honorary Fellow of the China Academy of Building Research.

Since 1958 Dr. Ketter has been associated with the State University of New York at Buffalo: Department Chairman, Dean of the Graduate School of Arts and Sciences, Vice President for Facilities Planning, President (1970-1982) and Leading Professor (1982-present). Prior to 1958 he was a member of the research staff of Fritz Engineering Laboratory of Lehigh University.

Dr. Ketter is author or co-author of a large number of technical and educational articles and chapters in recognized journals and books in four different countries, and is co-author of four recognized texts. He has been chairman or member of many national and international technical committees, and has represented the United States on several international organizations or commissions.

Mr. WALGREN. Thank you, Dr. Ketter. Mr. Mabey.

Mr. MABEY. Thank you for inviting me to appear before the committee and for the opportunity to report on a cooperative program of earthquake hazard reduction in Utah involving the U.S. Geological Survey and my organization, the Utah Geological and Mineral Survey. This program is nearing the end of its third year.

Utah has not experienced a highly destructive earthquake in a major population center since the first permanent settlements were established 140 years ago. However, every earth scientist that I know who has examined the geologic record agrees that on the average of once every few hundred years, earthquakes have occurred in the area where 90 percent of Utah's population reside, and they agree that Utah should be prepared for a major earthquake to occur at any time.

The thrust of our earthquake program in Utah is to prepare for the first disastrous earthquake. We want to take actions now before the first highly destructive earthquake hits the Wasatch Front population center; actions that will minimize the loss of life, destruction of property and the disruption to the economy of Utah and the Intermountain region. Because our knowledge of the earthquake hazard is based on scientific research rather than experience, the earthquake research conducted by and supported by the USGS is essential to our effort.

Prior to the start of this program in 1983, research largely supported by the USGS and the National Science Foundation had established that a serious earthquake hazard existed in the Wasatch Front area, and provided general indications of what we could expect from a first major earthquake. However, there were no state or local government agencies actively promoting earthquake hazard reduction and few actions were being taken to improve earthquake safety.

This was the status when the USGS approached the Utah Geological and Mineral Survey with a proposal to develop a cooperative program for earthquake hazard reduction for the Wasatch Front area of Utah.

In a series of meetings between these two organizations, the objectives of a three-year program were defined. Five elements were included: hazard definition, strong motion modeling, loss estimation modeling, information systems and implementation. This last element, implementation, was to receive particular emphasis.

We have made significant progress in all elements. In the hazard definition element, a particularly important development is the improved understanding of the recurrence rate for major earthquakes on the Wasatch Fault. In this element, state geologists have worked with USGS experts and been trained by them. As a result, we have a much better trained staff of geologists in Utah than we had before. As a part of the strong motion element, a badly needed network of strong motion instruments has been installed.

In the information area, we have dramatically improved the communication between groups concerned with earthquake hazard reduction in the region. The quarterly publication, the Wasatch Forum, has been established. We have conducted several workshops, some general and others targeted to specific groups or organizations, and we are translating the results of the scientific research into a series of interpreted maps and reports that can be used directly by planners, engineers and others. A computer-based system developed by the USGS for managing and applying earthquake and other geologic hazards information has been transferred to our state computer system.

The earthquake hazard received substantial publicity in newspaper reports, editorials and in radio and television broadcasts. Public awareness of the hazard has substantially increased.

We have developed effective coordination between the Utah Geological & Mineral Survey and the USGS hazards investigation and research programs on one hand, and the State Division of Comprehensive Emergency Management who manages the FEMA-supported earthquake response and educational programs, on the other. In Utah, I can assure you that there is good cooperation between these two agencies in the earthquake area.

We are particularly pleased with the progress related to implementation. In Utah, most responsibilities for actions involving earthquake hazard reduction are at the city and county level. We concluded that if local governments had a hazard geologist on their staffs to work with the county and city planning and engineering departments and to advise other officials, actions to promote seismic safety would be more likely to occur.

We proposed a program with the USGS providing temporary funding salaries for the hazard geologists for four Wasatch Front counties. The Utah Geological & Mineral Survey agreed to organize the program and supervise it with the counties providing administrative support.

The USGS agreed to this, the counties agreed and the program was established. The four most populous counties are now employing three geologists, with the two smallest of these counties sharing one geologist. The program has been a major success. Local governments are now using geology in the development and review of projects much more than before. And most important, even though all four counties have severe budget problems, they have tentatively agreed to continue the employment of the geologists after the Federal funding is terminated next year.

Another important need was to establish an earthquake information office at the State level to provide a continuing source of earthquake hazard information and to advocate seismic safety measures. Two weeks ago, despite budget problems that required reduction of appropriations to most state agencies to 91 percent of the current year's level, the Utah State Legislature approved new state funding for an Earthquake Hazard Information Officer. We consider this another major step.

Since the start of the program, seven Wasatch Front cities have adopted geologic hazard ordinances with seismic safety elements. Included are the three of the state's four largest cities, Salt Lake, Provo and Ogden; two more cities in three of the four targeted counties are currently developing similar ordinances.

The progress made in three years by the Wasatch Front Earthquake Hazard Reduction Program is impressive. We have obtained a significantly improved understanding of the hazard, we have greatly improved public awareness of the hazard, State technical personnel are better trained, we developed systems for managing and communicating hazard information, we have developed through the county geologists program a system for utilizing information at the local level, and most importantly, we have obtained an impressive commitment from all levels of government and from several sectors of the private economy as well to actions to reduce the earthquake hazard.

I can assure you that the efforts of the U.S. Geological Survey Earthquake Hazard Reduction Program in the Wasatch Front area of Utah are accomplishing the defined objectives. It is an outstanding example of a Federal effort aiding a state to accomplish a program that the State had neither the funding nor the technical resources to do alone.

Similar programs can be expected to work in other areas. I recommend that they be supported. I also want to stress that the success of the Wasatch Front program was achieved because there was a strong foundation of scientific research on earthquake hazards and on earthquake monitoring built by years of work supported by the National Earthquake Hazard Reduction Program over many years. Any substantial reduction in this research or monitoring program will, in effect, undermine this foundation and in the long run I think prove unwise.

[The prepared statement of Mr. Mabey follows:]

PREPARED STATEMENT OF DON R. MABEY, DEPUTY DIRECTOR, UTAH GEOLOGICAL AND MINERAL SURVEY

Utah has not experienced a highly destructive earthquake in a major population center since the first permanent settlements were established 140 years ago. However, every earth scientist that I know, who has examined the geologic record, agrees that on the average of once every few hundred years major earthquakes have occurred in the area where 90 percent of Utah's population resides, and they agree that Utah should be prepared for a major earthquake to occur at any time.

It was G.K. Gilbert, one of the U.S. Geological Survey's and this Nation's most famous geologists, who first warned of the earthquake hazard to Salt Lake City. In 1883, four years after the USGS was organized, Gilbert wrote the first paper by a USGS scientist on earthquakes and it was published on the front page of the Salt Lake Daily Tribune. In this paper, he documented the geologic evidence that Salt Lake City was in an active earthquake zone and pointed out the vulnerability of many buildings in Salt Lake City to earthquakes. He concluded by stating:

"It is useless to ask when this disaster will occur. Our occupation of the country has been too brief for us to learn how fast the Wasatch grows: and, indeed, it is only by such disasters that we can learn. By the time experience has taught us this, Salt Lake City will have been shaken down and its surviving citizens will have sorrowfully rebuilt it of wood: to use a homely figure, the horse will have escaped, and the barndoor, all too late, will have been closed behind him."

The thrust of our earthquake program in Utah is to avoid what Gilbert predicted. We want to take actions now, before the first highly destructive earthquake hits the Wasatch Front population center; actions that will minimize the loss of life, destruction of property and the disruption to the economy of Utah and the Intermountain Region. Because our knowledge of the earthquake hazard is based on scientific research rather than experience, the earthquake research conducted by or supported by the USGS is essential to this effort.

Prior to 1983, research, largely supported by the USGS and NSF, had established that a serious earthquake hazard existed in the Wasatch Front area and provided general indications of the major effects to be expected when an earthquake occurs. The University of Utah Seismograph Stations—with substantial funding support from the National Earthquake Hazards Reduction Program—was operating a network of seismograph stations. In 1981, the Utah Seismic Safety Advisory Council, funded by the State of Utah with technical assistance from the USGS, had published a list of recommended seismic safety actions but the recommendations were generally being ignored. There was no state or local government agencies actively promoting earthquake hazard reduction. This was the status when the USGS approached the Utah Geological and Mineral Survey with a proposal to develop a cooperative program of Earthquake Hazards Reduction for the Wasatch Front area of Utah.

In a series of meetings between the two organizations the objectives for a three year program were defined. Five elements were included: (1) Hazard Definition, (2) Strong Motion Modeling, (3) Loss Estimation Modeling, (4) Information Systems, (5) Implementation. This last element, implementation, was to receive particular emphasis. We have made significant progress in all elements. In the hazard definition element a particular important development is the improved understanding of the recurrence rate of major earthquakes on the Wasatch fault. In this element state geologists have worked with and been trained by USGS experts working in Utah. As a result of this training Utah now has a staff much better trained to conduct earthquake investigations. As part of the strong motion element a badly needed network of strong motion instruments has been installed.

In the information area we have dramatically improved communication between groups concerned with earthquake hazard reduction in the region. A quarterly earthquake publication, *The Wasatch Forum*, was established. It is printed and distributed by the state but has been edited by a USGS information specialist. Beginning this summer one of our staff will become editor. We have conducted several workshops—some general and others targeted at specific groups or organizations. We are translating the results of the scientific research into a series of interpreted maps and reports that can be used directly by planners, engineers and others. A computer based system developed by the USGS for managing and applying earthquake and other geologic hazard information has been transferred to the state computer system.

The earthquake hazard has received substantial publicity in newspaper reports and editorials and in radio and television broadcasts. A particularly important hour-long documentary on the Wasatch Front earthquake hazard entitled "When—Not If" was recently broadcast twice in prime time by one of Salt Lake City's major television stations. Public awareness of the hazard is high.

We have developed effective coordination between the Utah Geological and Mineral Survey and USGS hazard investigation programs on one hand and the State Division of Comprehensive Emergency Management, who manages the FEMA supported earthquake response and education programs, on the other.

We are particularly pleased with progress related to implementation. In Utah most responsibilities for actions involving earthquake hazard reduction are at the city and county levels. We concluded that if the local governments had a hazards geologist on their staffs to work with county and city planning and engineering departments and advise other officials, actions to promote seismic safety would be more likely. We proposed a program with the USGS providing temporary funding for the salaries of hazards geologists for the Wasatch Front counties, the Utah Geological and Mineral Survey organizing and supervising the program and the counties providing administrative support. The USGS and the counties agreed and the program was established. The four most populous counties are employing three geologists with the two smallest of these four counties sharing one geologist. The program is a major success. The local governments are now using geology in the development and review of projects much more than before. And most important, even though all four counties have severe budget problems, they have tentatively agreed to continue the employment of the geologists after the Federal funding is terminated next year.

Another important need was to establish an Earthquake Information Office at the State level to provide a continuing source of earthquake hazard information and advocate seismic safety measures. Two weeks ago, despite budget problems that required reduction of appropriations to most state agencies to 91 percent of current year's level, the Utah State Legisture approved new state funding for an Earthquake Hazard Information Officer—another major advance.

Since the start of the program seven Wasatch Front cities have adopted geologic hazard ordinances with earthquake safety elements. Included are three of the state's four largest cities—Salt Lake City, Provo and Ogden. Two more cities and three of the four targeted counties are currently developing similar ordinances.

Overall, the program has been a major success but some phases have not worked as well as others. The procedures for awarding grants does not always produce the most needed research, and we have not been completely successful in coordinating individual projects funded under the grants program with other activities in the Wasatch Front program. Although coordination with USGS projects has been generally good, the state of Utah has not been able to work as well with the Loss Estimate Studies projects as we had hoped.

The progress made in three years by the Wasatch Front Earthquake Hazard Reduction Program is impressive. We have obtained a significantly improved understanding of the earthquake hazard. We have greatly improved public awareness of earthquake hazards. We have greatly improved public awareness of earthquake hazards. State technical personnel are better trained. We have developed systems for managing and communicating hazard information. We have developed, through the County Hazards Geologist Program, a system for utilizing the information at the local level, which we believe will continue. And most importantly, we have obtained an impressive commitment from all levels of government to actions to reduce the earthquake hazard.

I can assure the committee that the efforts of the U.S. Geological Survey Earthquake Hazard Reduction Program in the Wasatch Front area of Utah are accomplishing the defined objectives. It is an outstanding example of a Federal effort aiding a state to accomplish a program that the state had neither the funding or technical resources to do alone. Similar programs can be expected to work in other areas, and I recommend that they be supported. I also want to stress that the success of the Wasatch Front Program was achieved because there was a strong foundation of scientific research on earthquake hazards built by years of work supported by the National Earthquake Hazards Reduction Program. Any substantial reductions in this research efforts will undermine this foundation and in the long run prove to be unwise.

Mr. **Brown** [presiding]. Thank you very much, Mr. Mabey. We will now hear from Mr. Fratto.

Mr. **Fratto**. Mr. Chairman, members of the Subcommittee on Science, Research and Technology, thank you for the invitation and opportunity to testify before you today regarding the National Earthquake Hazards Reduction Program.

My name is Edward Fratto and I am manager of the Earthquake Preparedness Program of the Massachusetts Civil Defense Agency and Office of Emergency Preparedness. Yes, Massachusetts.

Believe it or not Massachusetts, New York, Missouri, Pennsylvania, Ohio and South Carolina have had damaging earthquakes. These States as well as other areas in the Western, Central and Eastern United States have the potential for major destructive earthquakes with billions of dollars of property and millions of people at risk.

My testimony today will address two issues of critical importance to the success of the NEHRP.

The first issue concerns FEMA's fiscal year 1988 proposed rule change to require States to match NEHRP funds. If this rule change is adopted it will substantially reduce the Nation's ability to prepare for, respond to and recover from a catastrophic earthquake.

In my opinion this proposed rule change is in direct conflict with the intent of Congress as expressed in the National Earthquake Hazards Reduction Act of 1977.

I believe Congress took this important action in recognition that a major earthquake would cause such extensive loss of life and property that it would be beyond the capability and resources of most State and local governments to adequately prepare for, respond to, and recover from the devastation.

In passing the Act Congress established the foundation for a national program to limit the potential earthquake related losses by an amount far greater than the Federal program costs through a multi-disciplined, multi-government, approach.

Simply stated, Congress enacted guidelines for a cost-effective program that would appropriate funds prior to an earthquake for the purpose of limiting loss of life and property when a major earthquake occurs in the United States.

Congress found and declared in the Act that all 50 States are vulnerable to the earthquake hazards and that at least 39 States are subject to major or moderate seismic risk; a large portion of the population of the United States lives in areas vulnerable to earthquake hazards; and that earthquakes have caused and can cause enormous loss of life, injury, destruction of property and economic and social disruption.

Accordingly, Congress in Section 5(g) of the Act made assistance available to the States to implement its provisions. Congress directed the President to develop an implementation program through appropriate agencies, departments or entities designated in the Act. In 1980 the Act was amended assigning to FEMA the primary responsibility to plan and coordinate the program.

Now here comes FEMA proposing a rule change for fiscal year 1988 to require States to match each NEHRP dollar provided through FEMA for hazard assessment, vulnerability studies, earthquake preparedness and response planning, public awareness and education, seismic advisory boards, mitigation planning and all related activity.

Funding for these programs has been and is presently available at the 100-percent level. The proposed rule change would significantly reduce emergency management funding for this critical natural hazard program at a time when the States' need for federal support is in fact increasing.

Presently, approximately $1.6 million or just two percent of the Act's appropriation is allocated to State and local emergency management programs. The inability of the States to match this limited Federal funding will further reduce this percentage to about one percent.

It will also cause many States to seriously consider no longer participating in the program. This allocation must be carefully reevaluated to better serve the State and local governments.

I am, therefore, irrevocably opposed to the cost sharing proposal presented by FEMA and to the recommended rule change. The States need more not less 100-percent NEHRP funds if adequate emergency management programs to mitigate and respond to a catastrophic earthquake are to be developed. The present amount of support to the States is minuscule considering the awesome proportion of the task.

In comparison, a report prepared by Mr. Chris Arnold for the National Science Foundation found that the City of Tokyo budgets $1.2 billion American dollars a year for earthquake planning measures. This equals about $105.00 per year per person. In Shizuoka Prefecture, Japan, earthquake counter measures cost approximately $95.00 per year per person.

The comparable figure for California has been quoted at 65-cents per person. My estimate for Massachusetts, approximately one cent per person for earthquake preparedness. These figures suggest that the Japanese regard a cost of approximately $100.00 per year per person as a reasonable figure for significantly reducing the probability of death, injury and property destruction from a major earthquake.

I respectfully recommend an increase in funding in fiscal year 1988 to the States for emergency management programs from the present two percent level to not less than ten percent of the total Act's appropriation.

I also recommend that these programs continue to be federally funded at 100-percent. Section 5(g) of the Act should be amended to reflect this minimum ten percent level of 100-percent Federal funding. These percentages and levels could then be re-evaluated on a yearly basis.

Given the magnitude of Federal cuts to the States in many domestic programs, the relative low priority given to earthquake preparedness and the fact that many State budgets are already established for fiscal year 1988 and fisal year 1989, for FEMA to abruptly implement this cost sharing proposal in fiscal year 1988 would be programmatic homicide.

The second issue I will address is that NEHRP continues to place far too much emphasis on research at the expense of practical application, thereby reducing program efficiency and effectiveness.

NEHRP like other hazard mitigation programs, combines research and practical application with the goal of limiting loss of life and property in the event of a catastrophic earthquake.

Figure two illustrates what I consider to be optimum research versus application proportions throughout the life of a hypothetical hazard mitigation program.

In a program's initial years, research would be funded at a rate considerably higher than application.

However, as the program evolves, research is completed and funds for application increase. This is a cyclical process.

As figure two illustrates, as more funds are allocated to application and goals are met, it is necessary to increase research appropriations and decrease amounts for application. The difference in the proportion of research versus application funds diminishes over time as program goals and objectives are met.

Since 1981 NEHRP has not adequately apportioned research and application funds with regard to emergency management.

Figure three illustrates the proportion of expenditures for research versus expenditures for emergency management. As figure three clearly demonstrates, funding for research has exceeded funding for emergency management application at a rate of ten to one.

Thus, less than two percent of the total appropriation supports state and local emergency management for earthquake preparedness. Approximately seven percent of the total appropriation goes to FEMA while enormous proportions are appropriated for the United States Geological Survey and NSF.

The Act's tenth anniversary will be celebrated in 1987. At this point in its maturity the proportion of expenditures for research versus application should approximate those illustrated in figure four.

This situation must be corrected immediately if progress is to be made toward reaching the goals of the Act before we have a major catastrophic earthquake in this country.

As I read this sentence, a major catastrophic earthquake could strike without warning almost anywhere in the United States and

I submit to you as a nation we are not adequately prepared. A 1983 report of the Comptroller General of the United States concluded the following.

> Progress has been slow in developing earthquake response plans at the State and local levels and in the private sector. Future progress will depend on adequate FEMA direction and on the resources available to those preparing the actual plans.

At present, perhaps with the exception of parts of California, State and local earthquake contingency planning is, in my professional judgement, inadequate to respond effectively to a large magnitude earthquake in or near a heavily populated area.

I recognize and support the need for research, however, additional emergency management effort and funding is essential. An example of practical research that has been accomplished are the NEHRP provisions for the development of seismic regulations for new buildings prepared by the Building Seismic Safety Council for FEMA in the proposed regulations for existing buildings.

The problem is that these types of provisions must be implemented at the state and local levels, and if funds are reduced their implementation is unlikely at best.

Thus, I respectfully recommend that a greater percentage of NEHRP funds be allocated to the States for practical application of the excellent research that has thus far been accomplished or is in process.

In closing, I would like to quote the words of Albert Einstein who had, when speaking of natural occurrences, been known to state emphatically that, "God does not throw dice with the universe."

I hate to disagree with Professor Einstein but God does throw dice with the universe when it comes to earthquakes and thus far as a nation we have beaten the odds. Our luck will change, however, and there will be a major catastrophic earthquake in this nation perhaps as some are saying before the turn of the century.

It may be in California, it may be in New York, it may be in Missouri, it might very well be in Boston. It is uncertain exactly where it may occur but it is certain that it will occur somewhere in this nation.

I urge the committee to reconsider FEMA's proposal before you today to further reduce funding for emergency management. In the words of Chairman Walgren, "We need to take a close look at this shortsighted approach that saves pennies now at a tremendous cost down the line."

And that cost, Mr. Chairman, members of the committee, will be measured in human lives. Thank you.

[The prepared statement of Mr. Fratto follows:]

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STATEMENT OF MR. EDWARD S. FRATTO
EARTHQUAKE PROGRAM MANAGER
COMMONWEALTH OF MASSACHUSETTS
CIVIL DEFENSE AGENCY AND
OFFICE OF EMERGENCY PREPAREDNESS

before

THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
HEARING ON EARTHQUAKE REAUTHORIZATION

MARCH 10, 1987

Mr Chairman, members of the Subcommittee on Science, Research and Technology. Thank you for the invitation and opportunity to testify before you today regarding the National Earthquake Hazards Reduction Program (NEHRP).

My name is Edward Fratto and I am manager of the Earthquake Preparedness Program of the Massachusetts Civil Defense Agency and Office of Emergency Preparedness.

Yes, Massachusetts.

Believe it or not Massachusetts, New York, Missouri, Pennsylvania, Ohio and South Carolina have had damaging earthquakes (see Attachment 1). These states as well as other areas in the Western, Central and Eastern U.S. have the potential for major destructive earthquakes with billions of dollars of property and millions of people at risk.

My testimony today will address two issues of critical importance to the success of the NEHRP.

The first issue concerns the Federal Emergency Management Agency (FEMA) FY'88 proposed rule change to require states to match NEHRP funds. If this rule change is adopted it will substantially reduce the nations ability to prepare for, respond to and recover from a catastrophic earthquake.

In my opinion this proposed rule change is in direct conflict with the intent of Congress as expressed in the National Earthquake Hazards Reduction Act of 1977 (Public Law 95-124 and the 1980 amendment to the Act, Public Law 96-427).

I believe Congress took this important action in recognition that a major earthquake would cause such extensive loss of life and property that it would be beyond the capability and resources of most state and local governments to adequately prepare for, respond to, and recover from the devastation.

In passing the Act Congress established the foundation for a national program to limit the potential earthquake related losses by an amount far greater than the federal program costs through a multi-disciplined, multi-government, approach. Simply stated, Congress enacted guidelines for a cost-effective program that would appropriate funds prior to an earthquake for the purpose of limiting loss of life and property when a major earthquake occurs in the United States.

Congress found and declared in the Act that all 50 states are vulnerable to the earthquake hazards and that at least 39 states are subject to major or moderate seismic risk; a large portion of the population of the United States lives in areas vulnerable to earthquake hazards; and that earthquakes have caused and can cause enormous loss of life, injury, destruction of property and economic and social disruption (see Attachment 2). Accordingly, Congress in Sec. 5(g) of the Act made assistance available to the states to implement its provisions. Congress directed the President to develop an implementation program through appropriate agencies, departments or entities designated in the Act. In 1980 the Act was amended assigning to FEMA the primary responsiblity to plan and coordinate the program.

Now here comes FEMA proposing a rule change for FY88 to require states to match each NEHRP dollar provided through FEMA for hazard assessment, vulnerability studies, earthquake preparedness and response planning, public awareness and education, seismic advisory boards, mitigation planning and all related activity. Funding for these programs has been and is presently available at the 100% level. The proposed rule change would significantly reduce emergency management funding for this critical natural hazard program at a time when the states' need for federal support is in fact increasing.

Presently, approximately $1.6 million, or just 2% of the Act's appropriation is allocated to state and local emergency management programs (see Figure 1). The inability of the states to match this limited federal funding will further reduce this percentage to about 1%. It will also cause many states to seriously consider no longer participating in the program. This allocation must be carefully re-evaluated to better serve the state and local governments.

I am, therefore, irrevocably opposed to the cost-sharing proposal presented by FEMA and to the recommended rule change. The states need MORE not LESS 100% NEHRP funds if adequate emergency management programs to mitigate and respond to a catastrophic earthquake are to be developed. The present amount of support to the states is minuscule considering the awesome proportion of the task (see Attachment 3).

In comparison, a report prepared by Mr. Chris Arnold, AIA, for the National Science Foundation, found that the City of Tokyo budgets $1.2 billion American dollars a year for earthquake planning measures. This equals about $105/per year/per person. In Shizuoka Prefecture, Japan, earthquake counter measures cost approximately $95 per year/per person. The comparable figure for California has been quoted at 65 cents per person. My estimate for Massachusetts: approximately 1 cent per person for earthquake preparedness. These figures suggest that the Japanese regard a cost of a approximately $100 per year/per person as a reasonable figure for significantly reducing the probability of death, injury and property destruction from a major earthquake (see Attachment 4).

Accordingly, I respectfully recommend an increase in funding in FY'88 to the states for emergency management programs from the present 2% level to not less than 10% of the total Act's appropriation. I also recommend that these programs continue to be federally funded at the 100% level. Section 5(g) of the Act should be amended to reflect this minimum 10% level of 100% federal funding. These percentages could then be re-evaluated on a yearly basis.

Given the magnitude of federal cuts to the states in many domestic programs, the relative low priority given to earthquake preparedness and the fact that many state budgets are already established for FY'88 and FY'89, for FEMA to abruptly implement this cost-sharing proposal in FY'88 would be programatic homocide.

The second issue I will address is that NEHRP continues to place far too much emphasis on research at the expense of practical application, thereby reducing program efficiency and effectiveness.

NEHRP like other hazard mitigation programs, combines research and practical application with the goal of limiting loss of life and property in the event of catastrophic earthquake.

Figure 2 illustrates what I consider to be optimum research vs. application proportions throughout the life of a hypothetical hazard mitigation program. In a program's initial years, research would be funded at a rate considerably higher than application. However, as the program evolves, research is completed and funds for applicaton increase. This is a cyclical process. As Figure 2 illustrates, as more funds are allocated to application and goals are met, it is necessary to increase research appropriations and decrease amounts for application. The difference in the proportion of research vs. application funds diminish over time as program goals and objectives are met.

Since 1981 NEHRP has not adequately apportioned research and application funds with regard to emergency management. Figure 3 illustrates the proportion of expenditures for research (USGS, NSF, NBS) vs. expenditures for emergency management (FEMA). As Figure 3 clearly demonstrates, funding for research has exceeded funding for emergency management application at a rate of 10:1. Thus, less than 2% of the total appropriation supports state and local emergency management for earthquake preparedness. Approximately 7% of the total appropriation goes to FEMA while enormous proportions continue to be appropriated for the United States Geological Survey (USGS) and the National Science Foundation (NSF). (See Attachment 5).

The Act's tenth anniversary will be celebrated in 1987. At this point in its maturity the proportion of expenditures for research vs. application should approximate those illustrated in Figure 4.

This situation must be corrected immediately if progress is to be made toward reaching the goals of the Act before we have a major catastrophic earthquake in this country. As I read this sentence, a major catastrophic earthquake could strike without warning almost anywhere in the United States and I submit to you as a nation we are not adequately prepared. A 1983 report of the Comptroller General of the United States concluded the following:

> "Progress has been slow in developing earthquake response plans at the State and local levels and in the private sector. Future progress will depend on adequate FEMA direction and on the resources available to those preparing the actual plans." (See Attachment 6).

At present, perhaps with the exception of parts of California, state and local earthquake contingency planning is, in my professional judgement, inadequate to respond effectively to a large magnitude earthquake in or near a heavily populated area.

I recognize and support the need for research, however, additional emergency management effort and funding is essential. An example of practical research that has been accomplished are the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings prepared by the Building Seismic Safety Council(BSSC) for FEMA. The problem is that these types of provisions must be implemented at the state and local levels, and if funds are reduced their implementation is unlikely. Thus, I respectfully recommend that a greater percentage of NEHRP funds be allocated to the states for practical application of the excellent research that has been thus far accomplished.

In closing I'd like to quote the words of Albert Einstein who had, when speaking of natural occurrences, been known to state emphatically that,

> "God does not throw dice with the universe"

I hate to disagree with Professor Einstein but God does throw dice with the universe when it comes to earthquakes and thus far as a nation we have beaten the odds. Our luck will change, however, and there will be major catastrophic earthquake in this nation, perhaps before the turn of the century.

It may be in California, it may be in New York, it may be in Missouri, it might very well be in Boston. It is uncertain exactly where it may occur but it is certain that it will occur somewhere in this nation.

I urge the committee to reconsider FEMA's proposal before you today to further reduce funding for emergency management.

In the words of Chairman Walgren,

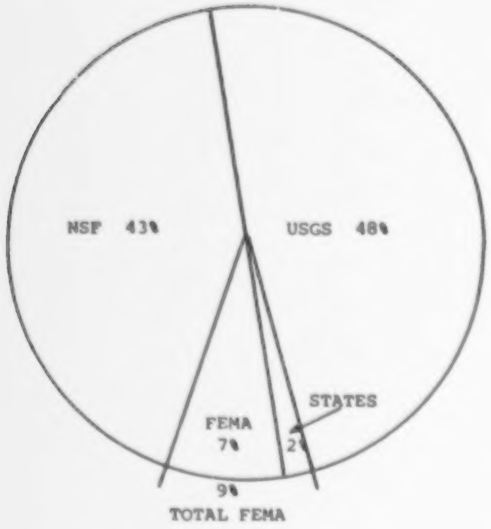
> "We need to take a close look at this shortsighted approach that saves pennies now at a tremendous cost down the line"

And that cost Mr. Chairman, members of the Committee will be measured in human lives.

Thank you.

* * * *

FY 87



FY 88 (PROPOSAL)

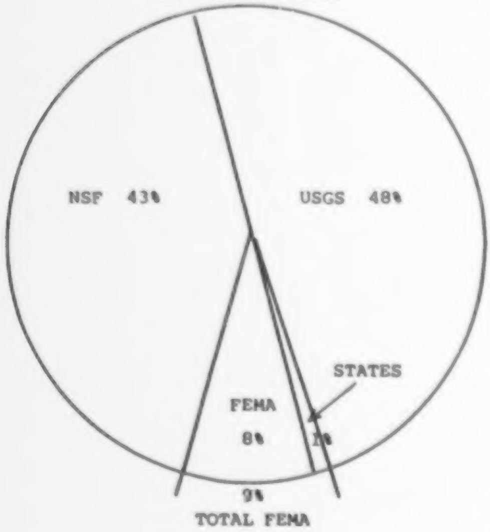


Figure 1.
NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM ALLOCATION OF FUNDS FY 87 AND PROPOSED FY 88

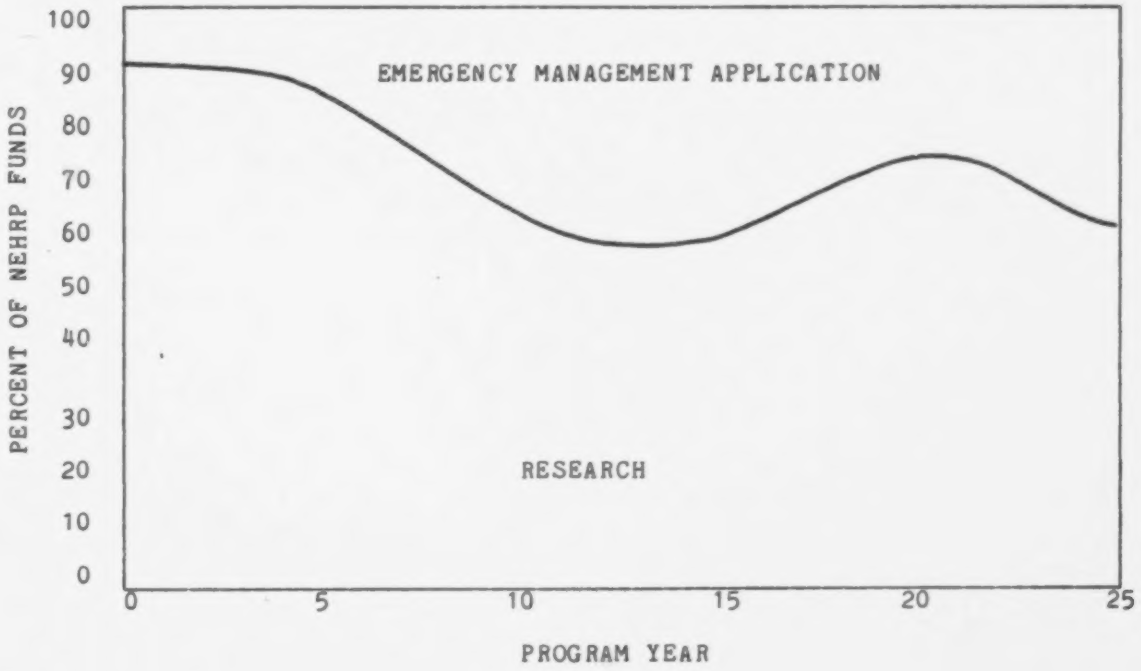


FIGURE 2. NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM
OPTIMUM LONG-TERM FUNDING

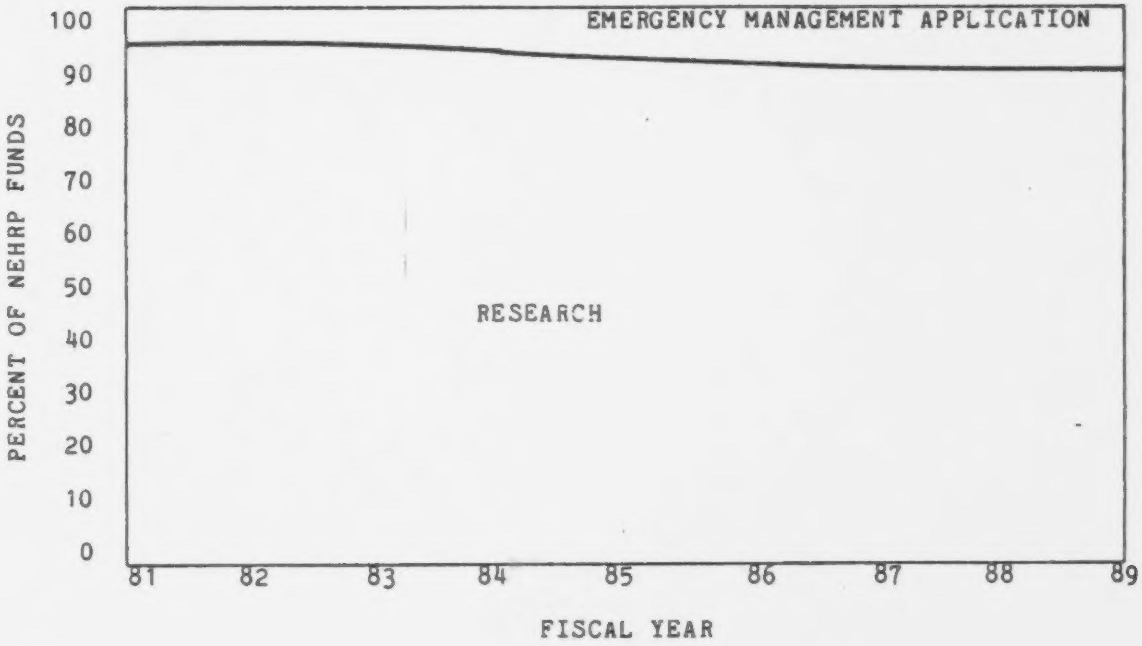


FIGURE 3. NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM FUNDING
FY'81-89

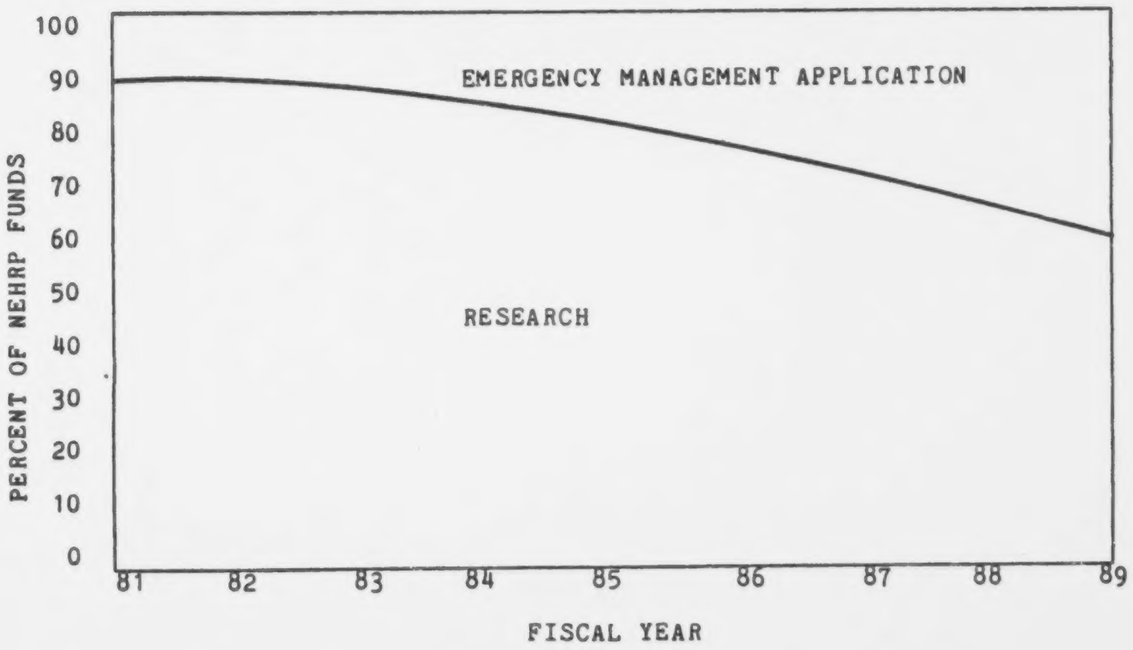
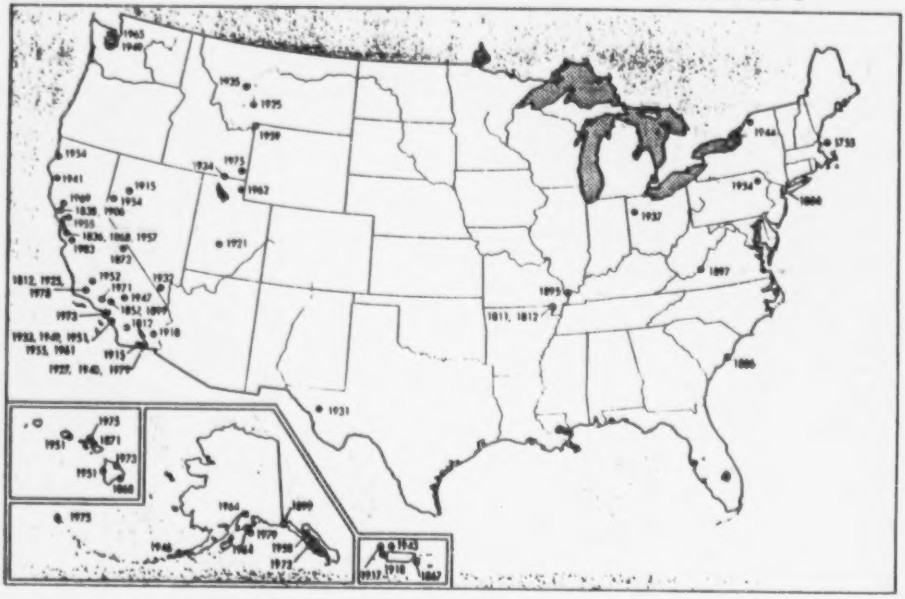


FIGURE 4. NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM OPTIMUM FUNDING FY'81-89

ATTACHMENT 1


1965
1949
1925
1935
1959
1954
1941
1915
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1975
1962
1869
1838, 1906
1955
1836, 1868, 1957
1983
1872
1921
1812, 1925,
1978
1952
1971
1947
1932
1852, 1899
1973
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1933, 1940, 1951,
1955, 1961
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1927, 1940, 1979
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1964
1958
1972
1943
1917
1918
1867
1944
1755
1934
1884
1937
1897
1895
1811, 1812
1886

Notable historic earthquakes in the United States that have caused damage are shown.

Significant, damaging earthquakes, 1755 to 1983, in the United States, Puerto Rico, and the Virgin Islands.
Damage in millions of dollars (1979 dollars)
[– do ––ditto]

Date	Location	Damage	Dead	Magnitude					M_o, $\times 10^{25}$ dyn cm
				M^1	$M_L{}^2$	$m_b{}^3$	$M_s{}^4$	M^5	
Nov. 18, 1755	Cape Ann, Massachusetts								
Dec. 16, 1811	New Madrid, Missouri					7.2	8.6	8.5	210
Jan. 23, 1812	---- do ----					7.1	8.4	7.5	210
Feb. 7, 1812	---- do ----					7.3	8.7	7.5	210
Dec. 8, 1812	San Juan Capistrano, California		40	6.9					
Dec. 21, 1812	Santa Barbara, California			7.1					

SOURCE: Geological Survey Circular 918 Report to the United States Congress

Significant, damaging earthquakes, 1755 to 1983, in the United States, Puerto Rico, and the Virgin Islands. Damage in millions of dollars (1979 dollars)—Continued

Date	Location	Damage	Dead	Magnitude					M_0 $\times 10^{25}$ dyn cm
				M^1	$M_L{}^2$	$m_b{}^3$	$M_s{}^4$	M^5	
June 10, 1836	Hayward, California			6.8					
June 1838	San Francisco, California			7.0					
Apr. 16, 1844	Off Puerto Rico			7¼					
Jan. 9, 1857	Fort Tejon, California						8.3	7.8-7.9	530-900
Nov. 18, 1867	Virgin Islands			7¾-8					
Apr. 2, 1868	Hawaii, Hawaii			7½-7¾					
Oct. 21, 1868	Hayward, California			6.8					
Feb. 19, 1871	Off Molokai, Hawaii			7					
Mar. 26, 1872	Owens Valley, California		27					7.8	500
Aug. 10, 1884	New York City, New York		0						
Aug. 31, 1886	Charleston, South Carolina		60			6.8		6.8	20
Oct. 31, 1895	Charleston, Missouri					6.2			
May 31, 1897	Giles County, Virginia		0						
Sept. 3, 1899	Cape Yakataga, Alaska			8.3					
Sept. 10, 1899	Yakutat Bay, Alaska			8.6					
Dec. 25, 1899	Hemet, California		6	6.6					
Apr. 18, 1906	San Francisco, California	2,000	700		6.8-7		8¼	7.7	350-430
June 22, 1915	El Centro, California	10.6	6						
Oct. 2, 1915	Pleasant Valley, Nevada		0	7¾					
July 26, 1917	Mona Passage, Puerto Rico			7.0					
Apr. 21, 1918	Riverside County, California	1.4	0				6.8		

Significant, damaging earthquakes, 1755 to 1983, in the United States, Puerto Rico, and the Virgin Islands. Damage in millions of dollars (1979 dollars)—Continued

Date	Location	Damage	Dead	Magnitude					$M_0 \times 10^{25}$ dyn cm
				M^1	$M_L{}^2$	$m_b{}^3$	$M_s{}^4$	M^5	
Oct. 11, 1918	Mona Passage, Puerto Rico	28.6	116				7.5		
Sept. 29, 1921	Elsinore, Utah		0						
Oct. 1, 1921	---- do ----		0						
June 27, 1925	Manhattan, Montana	1.8	0			6¾			
June 29, 1925	Santa Barbara, California	47	13		6.2				
Jan. 1, 1927	Imperial Valley, California	5.4	0		5.8				
Aug. 16, 1931	Mount Livermore, Texas		0	6.4					
Dec. 20, 1932	Cedar Mountain District, Nevada		0	7.3					
Mar. 11, 1933	Long Beach, California	266	115		6.3	6¼		6.2	2
Mar. 12, 1934	Kosmo, Utah		0	6.6					
Oct. 19, 1935	Helena, Montana	19	2				6.2		
Oct. 31, 1935	---- do ----	6	2				6.0		
Mar. 2, 1937	Anna, Ohio		0						
May 19, 1940	Imperial Valley, California	33	9		6.4		6.7	7.0	30
Nov. 14, 1941	Torrance, California	5	0				5.4		
July 28, 1943	Off Puerto Rico			7¾					
Sept. 5, 1944	Massena, New York	8	0				5.6		
Apr. 1, 1946	Unimak Island (Aleutians), Alaska	90	173				7.4		
Apr. 10, 1947	Barstow, California		0				6.4		
Apr. 13, 1949	Olympia, Washington	80	8				7.0		
Nov. 18, 1949	Long Beach Harbor, California	30	0		3.7				

Significant, damaging earthquakes, 1755 to 1983, in the United States, Puerto Rico, and the Virgin Islands. Damage in millions of dollars (1979 dollars)—Continued

Date	Location	Damage	Dead	Magnitude					M_o × 10^{25} dyn cm
				M^1	M_L^2	m_b^3	M_s^4	M^5	
Aug. 15, 1951	---- do ----	9	0						
Aug. 21, 1951	Kona, Hawaii		0				6.9		
July 25, 1952	Kern County, California	150	12		7.2		7.7	7.5	200
Aug. 22, 1952	Bakersfield, California	30	2				5.8		
Feb. 21, 1954	Wilkes-Barre, Pennsylvania	3	0						
July 6, 1954	Fallon, Nevada		0				6.8		
Dec. 16, 1954	Dixie Valley, Nevada		0	7.1					
Dec. 21, 1954	Eureka, California	6	1				6.6		
Jan. 25, 1955	Long Beach Harbor, California	8	0						
Oct. 23, 1955	Concord, California	3	1				5.4		
Mar. 9, 1957	Andreanof Islands (Aleutians), Alaska	8	0				8.3	9.1	
Mar. 22, 1957	Daly City, California	3	0				5.3		
July 9, 1958	Lituya Bay, Alaska		5				7.9	8.2	
Aug. 18, 1959	Hebgen Lake, Montana	26	28				7.1		
Apr. 4, 1961	Long Beach Harbor, California	11	0						
Aug. 30, 1962	Cache County, Utah	5	0				5.8		
Mar. 27, 1964	Prince William Sound, Alaska	1,020	131				8.4	9.2	82,000
Apr. 29, 1965	Seattle, Washington	28	7				6.5		
Oct. 1, 1969	Santa Rosa, California	13	0				5.6		
Feb. 9, 1971	San Fernando, California	900	58		6.4		6.6	6.6	10
July 30, 1972	Southeastern Alaska		0	7.6					

Significant, damaging earthquakes, 1755 to 1983, in the United States, Puerto Rico, and the Virgin Islands. Damage in millions of dollars (1979 dollars)—Continued

Date	Location	Damage	Dead	Magnitude					M_0, × 10^{25} dyn cm
				M[1]	M_L[2]	m_b[3]	M_s[4]	M[5]	
Feb. 21, 1973	Point Mugu, California	2	0				5.2		
Apr. 26, 1973	Hilo, Hawaii	9	0				6.2		
Feb. 2, 1975	Near Islands, Alaska		0	7.6					
Mar. 28, 1975	Pocatello Valley, Idaho	1	0				6.1		
Nov. 29, 1975	Kalapana, Hawaii	5	2				7.2		
Aug. 13, 1978	Santa Barbara, California	15	0				5.6		
Feb. 28, 1979	St. Elias, Alaska		0	7.1					
Oct. 15, 1979	Imperial Valley, California	21.1	0		6.6			6.5	6
May 2, 1983	Coalinga, California	31	0		6.7	6.2	6.5	6.4	5

[1] Unreferenced magnitude.

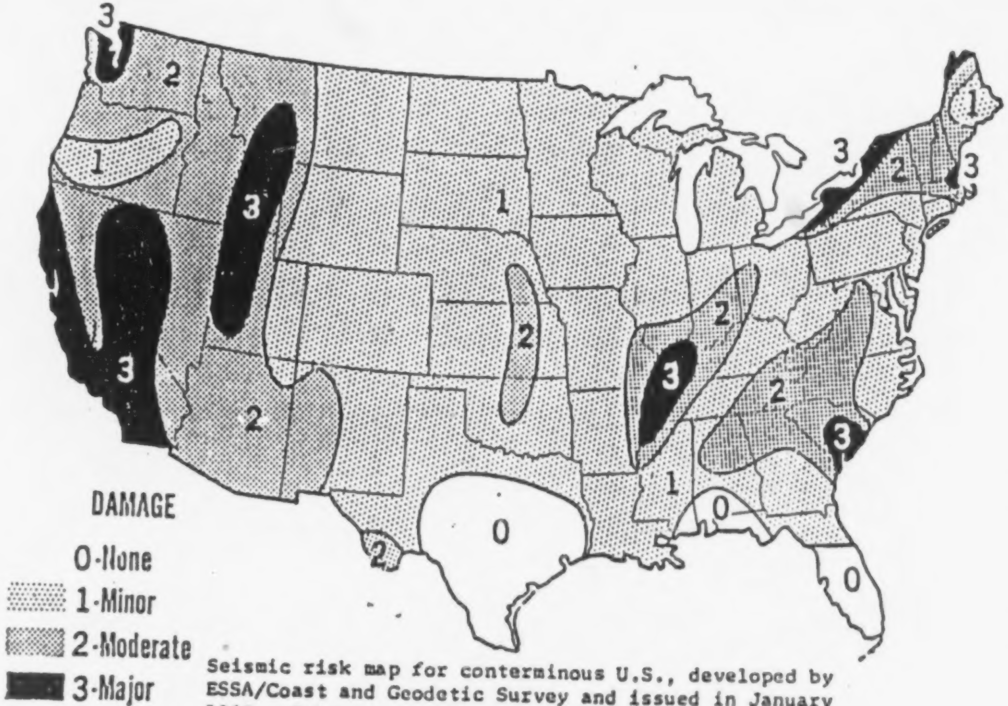
[2] Local (Richter) magnitude.

[3] Body-wave magnitude.

[4] Surface-wave magnitude.

[5] Moment magnitude.

ATTACHMENT 2


DAMAGE
0-None
1-Minor
2-Moderate
3-Major
3
2
1
3
3
2
1
2
3
2
3
2
3
1
0
0
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1
3

Seismic risk map for conterminous U.S., developed by ESSA/Coast and Geodetic Survey and issued in January 1969. Subject to revision as continuing research warrants, it is an updated edition of the map first published in 1948 and revised in 1951." The map divides the U. S. into four zones: Zone 0, areas with no reasonable expectancy of earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, where major destructive earthquakes may occur.

TABLE 11.—*U.S. population-at-risk by seismic risk zone and state*

[From Ayre, 1975]

State	Total Population	Estimated Population-at-Risk by Seismic Risk Zone			
		Zone 0	*Zone 1*	*Zone 2*	*Zone 3*
Alabama	3,444,165	1,056,000	1,126,000	1,263,000	0
Alaska	300,382	0	6,000	25,000	270,000
Arizona	1,722,482	0	0	1,742,000	30,000
Arkansas	1,923,295	0	1,473,000	166,000	284,000
California	19,953,134	0	0	2,636,000	17,317,000
Colorado	2,207,259	0	2,207,000	0	0
Connecticut	3,032,217	0	2,948,000	85,000	0
Delaware	548,104	0	548,000	0	0
Florida	6,789,443	5,503,000	1,286,000	0	0
Georgia	4,589,575	0	1,777,000	2,812,000	0
Hawaii	768,324	30,000	637,000	39000	63 000
Idaho	712,567	0	0	513,000	200,000
Illinois	11,113,976	0	9,951,000	895,000	268,000
Indiana	5,193,669	0	2,350,000	2,608,000	236,000
Iowa	2,825,041	0	2,825,000	0	0
Kansas	2,249,071	0	1,907,000	342,000	0
Kentucky	3,219,311	0	1,349,000	1,467,000	403,000
Louisiana	3,643,180	0	3,643,000	0	0
Maine	993,663	0	318,000	675,000	0
Maryland	3,922,399	0	3,734,000	189,000	0
Massachusetts	5,689,170	0	0	1,980,000	3,709,000
Michigan	8,875,083	0	8,875,000	0	0
Minnesota	3,805,069	0	3,805,000	0	0
Mississippi	2,216,912	269,000	1,674,000	217,000	57,000
Missouri	4,676,501	0	3,079,000	1,389,000	209,000
Montana	694,409	0	240,000	313,000	142,000
Nebraska	1,483,791	0	1,206,000	278,000	0
Nevada	488,738	0	0	300,000	189,000
New Hampshire	737,681	0	0	738,000	0
New Jersey	7,168,164	0	7,168,000	0	0
New Mexico	1,016,000	0	536,000	480,000	0
New York	18,236,967	0	13,211,000	2,481,00	2,545,000
North Carolina	5,082,059	0	2,172,000	2,910,000	0
North Dakota	617,761	0	618,000	0	0
Ohio	10,652,017	0	7,863,000	2,789,000	0
Oklahoma	2,559,253	0	2,399,000	160,000	0
Oregon	2,091,385	0	539,000	1,539,000	13,000
Pennsylvania	11,793,909	0	11,347,000	183,000	264,000
Rhode Island	946,725	0	84,000	863,000	0
South Carolina	2,590,516	0	0	1,577000	1,013,000
South Dakota	665,507	0	666,000	0	0
Tennessee	3,923,687	0	1,165,000	1,810,000	949,000
Texas	11,196,730	9,859,000	1,325,000	13,000	0
Utah	1,059,273	0	40,000	48,000	972,000
Vermont	444,330	0	0	444,000	0
Virginia	4,648,494	0	2,435,000	2,213,000	0
Washington	3,409,169	0	0	1,240,000	2,169,000
Washington, D.C.	756,510	0	757,000	0	0
West Virginia	1,744,237	0	1,509,000	236,000	0
Wisconsin	4,417,731	0	4,418,000	0	0
Wyoming	332,416	0	308,000	19,000	5,000
Totals	203,223,000 (100%)	16,717,000 (8%)	115,091,000 (57%)	40,412,000 (20%)	30,973,000 (15%)

SOURCE: USGS Professional Paper 941-B

ATTACHMENT 3

FEMA NEHRP FUNDS ALLOCATED TO THE STATES AND TERRITORIES

FY'87

STATE	AMOUNT
Alaska	60,000
Arkansas	37,770
California	662,500
*Central United States Earthquake Consortium (CUSEC)	255,000
Hawaii	59,500
Illinois	20,000
Indiana	20,000
Kentucky	27,500
Massachusetts	65,000
Mississippi	20,000
Missouri	31,755
New York	69,000
Puerto Rico (Ter.)	36,000
South Carolina	60,000
Tennessee	35,000
Utah	50,000
Virgin Islands (Ter.)	30,000
Washington	60,000
	1,599,025

* Consortium supports the states of Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, Tennessee.

SOURCE: Developed based on information provided by FEMA

ATTACHMENT 4

Earthquake Disaster Prevention Planning in Japan

by

Christopher Arnold, A.I.A.

November 1982

A study conducted by Building Systems Development, Inc.,
San Mateo, California
under a grant from the National Science Foundation,
Washington, D.C.

IX. Cost

What do these extensive counter earthquake measures cost? Although it is difficult to get specific comparable figures, two budgets are worth noting. The counter earthquake planning measures for the City of Tokyo are budgeted at $1.2 billion American dollars a year. This seems like, and is, an enormous sum of money by American standards, but Tokyo is an enormous city and this sum represents approximately $105/per year/per person. The extensive countermeasures in Shizuoka Prefecture are costing approximately $320 million a year or $95/per year/per person. The comparable figure for California has been quoted as 65 cents per person.* These figures suggest that the Japanese regard a cost of approximately $100/per year/per person for significantly reducing the probability of death, injury or property destruction resulting from a major earthquake as a reasonable figure.

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* Article by Frank J. Schober, Jr., "When the Earthquake Comes...", Los Angeles Times, November 3, 1982, Part II, page 7.

ATTACHMENT 5

NEHRP FUNDING DISTRIBUTION
(HISTORICAL AND PROJECTED)
FY 1981 - 1989

AGENCY	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989
USGS	32,300,000 55%	32,652,000 56%	34,545,000 57%	35,524,000 55%	36,914,000 52%	34,025,000 49%	34,892,000 48%	35,733,000 48%	36,542,000 48%
NSF	23,639,000 41%	23,657,000 41%	22,908,000 37%	25,056,000 39%	27,760,000 39%	29,665,000 43%	30,940,000 43%	32,178,000 43%	33,368,000 44%
FEMA	1,543,000 3%	1,333,000 2%	3,120,000 5%	3,705,000 6%	5,705,000 8%	5,967,000 9%	6,224,000 9%	6,473,000 9%	6,713,000 9%
NBS	425,000 .7%	425,000 .7%	450,000 .7%	475,000 .7%	499,000	-0-	-0-	-0-	-0-
TOTAL	57,907,000	58,067,000	61,023,000	64,760,000	70,878,000	69,657,000	72,056,000	74,384,000	76,623,000

USGS Total for 1981 32,300 (FY'81 funds were not allocated by the USGS
per the five program categories until FY'82)

Note: FY'81 - FY'84 Historical Data Obtained from Representative Agencies
FY'85 - FY'89 Data from "National Earthquake Hazards Reduction Program - Five-Year Plan" dated December 1984

Source: Developed based on information provided by FEMA

ATTACHMENT 6

REPORT BY THE
Comptroller General
OF THE UNITED STATES

Stronger Direction Needed For The National Earthquake Program

The Federal Emergency Management Agency (FEMA), the lead agency for the National Earthquake Program, needs to do more to fulfill the requirements of the Earthquake Hazards Reduction Act of 1977. FEMA's newly formed Earthquake Policy Review Group can provide needed direction to the Federal agencies in the program by improving interagency planning, budgeting, and evaluation.

Progress has been slow in developing earthquake response plans at the State and local levels and in the private sector. Future progress will depend on adequate FEMA direction and on the resources available to those preparing the actual plans.

An operational earthquake prediction system--an objective of the 1977 act--has not been developed because necessary technological advances have not occurred. Current monitoring systems can produce warnings that geological conditions suggest an impending earthquake, but not routine predictions. Further basic research is needed before reliable short-term predictions are feasible.

UNITED STATES GENERAL ACCOUNTING OFFICE

GAO/RCED-83-103
JULY 26, 1983

EDWARD S. FRATTO

Mr. Fratto is Manager of the Massachusetts Civil Defense Agency and Office of Emergency Preparedness Earthquake Hazard Mitigation Program. He was appointed to his present position in 1983 and has been employed by the Agency since 1981. In 1979 and 1980, he was with the Planning Department of the City of Malden, Massachusetts. His particular area of interest and expertise is public policy analysis and hazard management.

Mr. Fratto is 33 years of age and resides in Natick, Massachusetts. In 1985, he received a Master of Urban Affairs from Boston University, where he specialized in public policy analysis and hazard management as it relates to the urban environment. He also holds a Master of Arts in Teaching from the University of Massachusetts at Amherst, which he received in 1979 and a B.S. in Psychology from Boston State College received in 1975.

Mr. Fratto's professional activities have concentrated primarily on earthquake hazard mitigation. He has been responsible for the overall management and coordination of several federally funded studies on the earthquake hazard in Massachusetts and New England. In 1983, under his direction, earthquake ground shaking maps were completed for Massachusetts. Presently, he is responsible for the Metropolitan Boston Area Earthquake Loss Study, the first of its kind on the east coast.

Among his many professional affiliations and activities, Mr. Fratto is Chairman of the New England Seismic Advisory Council (NESAC), a member of the National Academy of Science, National Research Council, Panel on Earthquake Loss Estimation Methodology, and a member of the USGS Boston Instrumentation of Structures Advisory Committee. Mr. Fratto is active in area of community and public safety and is Chairman of the Natick Police-Fire Consolidation Committee and a member of the Massachusetts Hazardous Waste Facility Site Safety Council.

Mr. Fratto has presented lectures, written numerous articles, and actively participated in many regional, national and international conferences on earthquakes and earthquake preparedness.

* * * *

Mr. **Walgren** [presiding]. Thank you very much, Mr. Fratto. We appreciate that and particularly that last reference. Let me recognize the gentleman from California, Mr. Brown.

Mr. **Brown**. Thank you, Mr. Chairman. Gentlemen, I am very appreciative of your testimony. I can remember 15 years ago when we would hold a hearing on a subject like this that we might get some testimony from California but we weren't likely to get the kind of excellent testimony that we have had here from Utah and New York and Massachusetts that we have.

We have had ten years of experience under the Act now. Some people thought at the time it was a boondoggle just for California. Actually, the genesis of the Act stemmed from major breakthroughs in fundamental research in the earth sciences, the development of the area of plate tectonics and other things plus an awareness of the fact that many other countries had outstripped the United States in their understanding of the rudimentary processes of earthquake prediction and in their understanding of the need to mitigate the hazards of earthquakes much more effectively.

It was those forces that led to the creation of the Act ten years ago, not the fact that we have earthquakes in California, believe me.

I am deeply disturbed at the testimony that indicates that over ten years we have seen a gradual erosion of the basic financial support for this program, eroded by inflation, by budgets which are maintained at roughly the same dollar level but whose purchasing power continues to decrease and I am also disturbed by the fact that we have not created the kind of vigorous leadership under the Act that was our intention.

It seems to be a classic case of where we have led a horse to water in the form of the Federal bureaucracy but we haven't made it drink yet. Now the promising thing and I don't want to just make a speech here is that we now have a situation where we have all regions of the United States actively involved in this.

What we need to do is to generate from that active involvement active political support for the level of budgets that are required here and I want to pose that question to you, gentlemen.

Do you think that we can build some political support amongst the Congressional delegations and others in your region that would support some modest increase in the level of funding to avoid the kind of cuts that we are having to make that we see and to re-invigorate the leadership that is needed in the Federal program? Is that something we can do and I will ask all of you to respond to that?

Mr. **Tobin**. Mr. Chairman and Congressmen, certainly you can count on California to be supportive in giving vigorous support because of the critical importance that the national program does have to our State and in my travels which included probably half a dozen States within the last six months, I can assure you that the interest and support is starting to grow there and the questions are being asked.

So I would answer, yes, I believe that we can give you some support in that endeavor.

Mr. **Brown**. New York has this large infusion of Federal money. Do any of the Congressmen in New York know about it yet? [Laughter.]

Besides Henry, Henry knows about it.

Mr. **Ketter**. From what I read in the California papers, they thought a lot of the Congressmen and Senators from the Eastern part of the United States knew about what was going on.

Mr. **Brown**. I hope that they were half as correct as they thought they were.

Mr. **Ketter**. I think our experience in securing the support that we have thus far is a pretty clear indication that if presented in the correct light, support is there. I have no doubt about that.

Mr. **Mabey**. I think the approach that the U.S. Geological Survey has used in Utah in which they involve the State not only in carrying out the program but in planning the program is very effective in generating local support and in generating support from the Congressional delegation.

I know we get inquiries from the Congressional delegation. We send them copies of our publications and our newsletter. So I would strongly recommend the effort to involve the State in the planning, make them feel that they have a stake and a partial ownership in the program and I think that will help generate the support.

Mr. **Fratto**. I think there is a potential for support in Massachusetts. It is going to take the leadership of this Committee to bring that to their attention. As one person with a typist, it is difficult for me to change an entire State but I think with the support of this Committee, yes. I think there would be support.

Mr. **Brown**. I think that is the stage that we are in right at this point where we are going to have to generate that additional support. This Committee has been religious in its support of this program over the years but we cannot continue to fight either a lack of commitment from the Administration, we can't fight these budgetary fights year after year without some additional backing from a lot more members many of whom regard this as some esoteric and specialized need that doesn't really involve them.

You gentlemen know and most of us on the Committee know that that is not the situation. This is the best example of sound long range investment for the benefit of the American people that can be made. We just don't realize it until the tragedy happens and then it is too late.

I have no further questions, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Brown. Mr. Nowak?

Mr. **Nowak**. I, too, would like to welcome all the panel members, especially Dr. Ketter who I have known for many, many years as President of the University System in Buffalo and certainly now he has this grave responsibility of the Center. I'm sure everyone is looking for the same type of results he had as President.

Doctor, if I could, I would like to first start off with one or two questions that have come up by some of my colleagues here and one is if you could more fully than your testimony does at the present time, describe your plans for technology transfer. That has become an inquiry that I have heard from several members.

Mr. **Ketter**. Technology transfer has a variety of meanings to a variety of people depending upon where they are at a given point in time. It is our view that the availability of information in a form which is usable to the end product user is what in fact will have the greatest impact. The difficulty is to anticipate what types of information will be needed and in what form.

We are convinced that this will not be a single piece of information but will in fact be approached from a variety of different ways. For example, we have over the last six months laid a fairly good background for rather massive, and I don't want to use that in the negative sense, but rather large national media coverage on earthquakes, that it has started and it will continue at an ever increasing rate to try to make the public generally aware. I'm not saying that people haven't done this, but I'm saying we have been doing this with a number of television stations, both in this country and in neighboring countries. We have worked with providing short 6 seconds—I beg your pardon—6 minutes to 15 minute quips that are being made available to television channels through the country, so that when they have a short spot, they can in fact go for it. That's one type of technology transfer. It's not the kind that we are spending most of our time on.

We are concerned that the practicing engineering profession, at least in the eastern part of the United States is somewhat deficient. The east has not recognized earthquakes as a major problem. It is necessary that we at least raise the consciousness level of a large number of practicing engineers and for this purpose, we are scheduling within the next six months, a series of conference workshops to try to bring them up to date.

For example, there is one this summer at Cornell where we have in fact put together over the last three to four years programs which will in fact allow practicing engineers to take into account the earthquake design problem for a particular region, but yet the practicing engineers in the east are not aware that these programs are available. Therefore, we are running a conference and we are bringing practicing engineers from the entire eastern seaboard to Cornell to see how they use these computer programs with interactive graphics, so they can see it is not that major a problem.

We are concerned with the whole question of how does the bond market in New York City, how does the insurance market in the New England States, come to grips with the question that should the east decide to upgrade its earthquake resistance design, there will have to be a very major input coming from these segments of the business community, so with the New York Academy of Sciences, we will hold this fall a major conference in New York City, where we will address the question of the earthquake hazard problem in the northeast United States, where the first day we will talk about establishing the basis for hazard projection, the second day we will talk about mitigation methods for new and for current buildings, and the third day, we will attempt to assess the building stock in the northeast. We expect 400 to 500 people in attendance there, including the bond market from the Wall Street area and so forth.

We will in fact at the same time hold conferences on expert systems, new approaches to handling the whole building design problem and we have developed several of these and we have had two engineering architect firms that have been willing to allow us on a workshop basis to use their current designs, to determine whether or not their current state of practice is where it should be and with the idea that a year or two years from now, we will be able to take those forward to the entire engineering profession as models for how it should be.

This is another indication of technology transfer. Simultaneously, we are working with the NSF in the development of these optical disks where we will in fact store all written knowledge that is available in the earthquake area and we would make it available at Buffalo and other places to anyone that might in fact seek this, at the absolute minimum cost.

Mr. NOWAK. Yes. I think that last statement brings me to another question, and maybe Mr. Tobin could answer first. Shouldn't there be a mechanism to establish and ensure collaborative effort here? Congressman Brown just talked about coalescing much larger constituencies for these types of programs. I wondered, you know, we have two great Centers here, where that could be brought together, so then you can have a large distribution out to start to generate, you know, that kind of support.

Mr. Tobin?

Mr. TOBIN. Yes, Mr. Chairman, Congressman, certainly we in California will work with anybody who is contributing to the earthquake safety problem. We have a history of working internationally as well as with other States and would welcome working with New York in terms of cooperative efforts.

I think that in Dr. Ketter's testimony, he has spoken to a very important problem that New York is concerned about, problems in the eastern United States, and apparently not as much in terms of problems in the western United States or in California.

I don't know what that chasm may well be between the two areas of interest. I can't think they are that great, but I think in answer to your question, yes, we would love to work cooperatively. It's a program that is too important to the entire nation as well as the State of California.

Mr. NOWAK. Dr. Ketter.

Mr. KETTER. If I might continue, we, too, are convinced this is not a regional problem. In fact, it's not even a national problem. It is a world problem but we have a national focus that we have to worry about. We focused on the eastern United States as a starting point, not because we felt this was the end point. We felt that California had done a magnificent job with respect to California. Sure, there are many things yet to be done but there was almost a void in the whole state of what is available for east of the Sierra's and we felt somebody had to address that in a very formal, hard fashion so that we can then subsequently bring both parts together.

As part of our program, we are involving people from California right at the present moment. Money from the Center at Buffalo is in California right as of this moment. It's in Berkeley. It's down in Los Angeles. It's in Denver. It's in Houston. We have, as I said, 80 some people that are working that we are funding in a national effort. True; we are spending a lot of time looking at what the problem is in the east because we think there has been too little done in that area.

Mr. NOWAK. Well, thank you very much. I think that certainly is the direction in which to proceed. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Nowak. Mr. Bruce?

Mr. BRUCE. I have no questions.

Mr. WALGREN. I think you have covered the area quite well. The operative word should be "outrageously underfunded," I gather, Mr. Tobin; is that correct?

Mr. TOBIN. Yes, Mr. Chairman. I strongly believe that's exactly the problem that we have. Your testimony over past years and Mr. Fratto has referred to the efforts that others have carried out, certainly when we look at the national interest in California alone in terms of employment, over 340,000 in the military, the defense contractors and all the other elements of activities, they are very directly national responsibilities.

The national government really isn't carrying its own. We are in a rowboat and one side is pulling harder than the others. I'm afraid in this case, it is California that is pulling much harder than the Federal Government is in earthquake safety in California.

Mr. WALGREN. Let me ask you this; when we think about how little is done in application and we see FEMA there, as I understand it, spending an awful lot of money on civil defense, a lot of target money and then relatively little in this area, and we are asked, for example, with the earth sciences at NSF, to understand that well, they are interested in doing science and they will select science programs and if some of the science programs happen to be in earthquakes, well then, well and good and that will be the earthquake effort.

Wouldn't it be fair to feel that FEMA should be putting much more in this applied local State government effort and if some of that happened to spill over into civil defense preparedness, which is almost a very close fit, then well and good? Would that be a reasonable approach from your standpoint?

Mr. TOBIN. Mr. Chairman, that's fundamental to my testimony. I think what we see is that the earthquake programs are supplementing other programs rather than the other way around. In the case of FEMA, the earthquake program makes 2.5 percent of their budget. We understand that because California isn't particularly keen on planning for nuclear war, that we are in the position of losing those emergency management funds for the basic emergency planning and management activities that are carried out by all local governments in California.

When we look at the effects of an earthquake, a large earthquake, it will be region-wide, not isolated. You are talking about in the Los Angeles area, 180 cities that have to compete for resources, for emergency response resources. We have to bring in resources from outside of that region, from the State—from other States. That is exactly the kind of impact I believe you would have in a very major war like situation, and we believe that the best way we can carry out emergency management in California is to look at these major Level III regional wide disasters, but yet we are faced with a potential cutoff of that program in California because of a strict reading of the statutes that govern the FEMA program.

I think we can make other examples. The National Science Foundation, I bristle with the idea that the earthquake program is used to support fundamental research in other aspects, as important as they are. I would rather see that the funds that are used to support fundamental studies of earth processes are being used to support the earthquake program, and that's a practical application. That's where people really are at risk.

I think you could probably find similar situations in the other agencies. It comes back to the situation where you are short on funding. We need priorities and we need leadership to carry out those priorities. I think that basically that's what we are here to say that this program needs.

Mr. WALGREN. Any other comments that anyone on the panel would like to make?

Mr. FRATTO. Yes, Mr. Chairman. I would support Mr. Tobin and his statements about preparing for natural hazards. I mean, I think this is where our emphasis should be on the natural and technological hazards. If our States and communities are prepared for that, you know, ultimately they could respond to any type of emergency, but to turn that around and focus on war related activity, saying as long as it doesn't detract from natural hazards, to me, seems to be not the way to go in terms of emergency management.

You have to take a comprehensive approach and it has to cover technological and natural hazards and disasters because we can get support for that type of emergency planning.

Mr. WALGREN. Thank you. Any other comments that people would like to make?

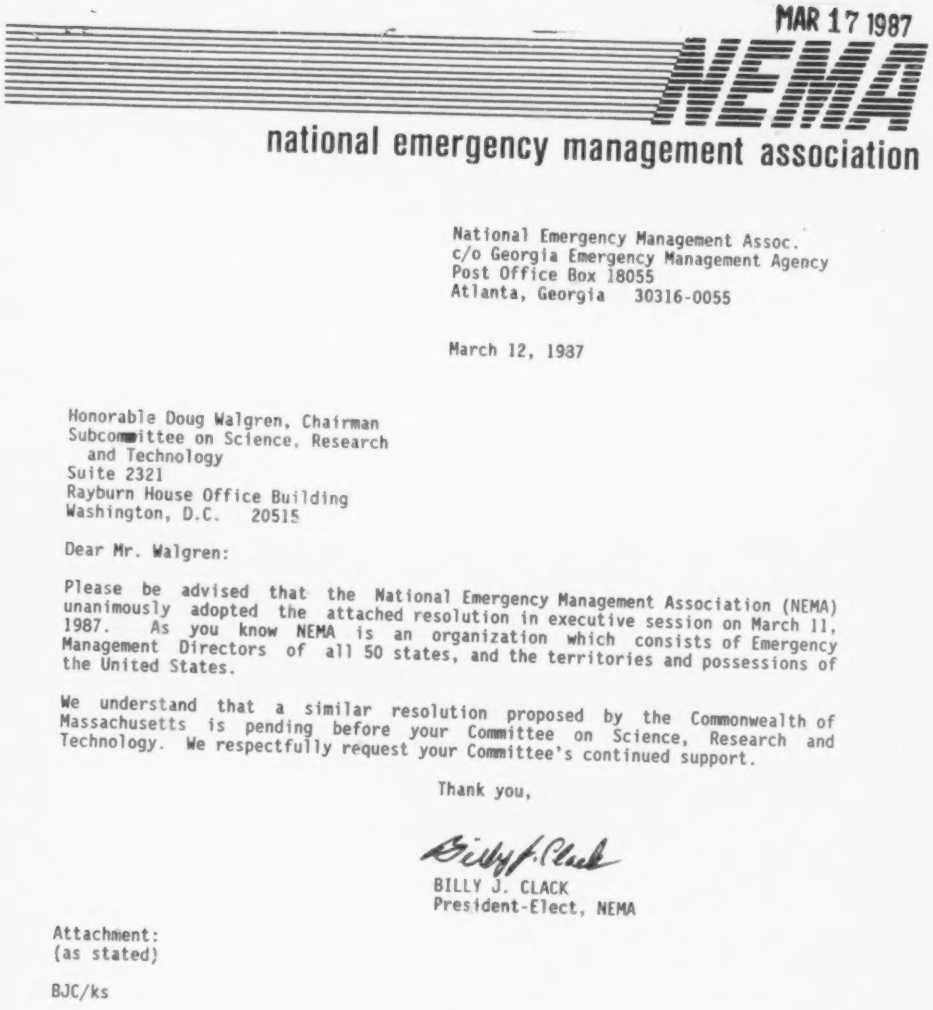
[No response.]

Mr. WALGREN. Well, let me express on behalf of the Committee our appreciation for your being a resource to us. We appreciate your contribution and look forward to working and talking with you about the directions that you are going and I hope you will continue to write us and give us insight into the directions which we should be pushing in.

Thank you very much.

[Whereupon, at 12:05 p.m., the Subcommittee recessed, to reconvene at the call of the Chair.]

APPENDIX



MAR 17 1987

NEMA
national emergency management association

National Emergency Management Assoc.
c/o Georgia Emergency Management Agency
Post Office Box 18055
Atlanta, Georgia 30316-0055

March 12, 1987

Honorable Doug Walgren, Chairman
Subcommittee on Science, Research
and Technology
Suite 2321
Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Walgren:

Please be advised that the National Emergency Management Association (NEMA) unanimously adopted the attached resolution in executive session on March 11, 1987. As you know NEMA is an organization which consists of Emergency Management Directors of all 50 states, and the territories and possessions of the United States.

We understand that a similar resolution proposed by the Commonwealth of Massachusetts is pending before your Committee on Science, Research and Technology. We respectfully request your Committee's continued support.

Thank you,

Billy J. Clack
BILLY J. CLACK
President-Elect, NEMA

Attachment:
(as stated)

BJC/ks

NATIONAL EMERGENCY MANAGEMENT ASSOCIATION

RESOLUTION
URGING AN INCREASE IN NATIONAL EARTHQUAKE HAZARD REDUCTION ACT FUNDS FOR EMERGENCY MANAGEMENT

WHEREAS, earthquakes have caused and will cause in the future enormous loss of life, injury, destruction of property and economic and social disruption, and

WHEREAS, the horrible impact of a major earthquake was vividly demonstrated in the recent earthquakes in El Salvador and Mexico City.

WHEREAS, all 50 states are vulnerable to the hazards of earthquakes and at least 39 of them are subject to major or moderate seismic risk, and

WHEREAS, the Congress of the United States has recognized through passage of the "Earthquake Hazards Reduction Act" (P.L. 95-124), that earthquake losses and disruption can be reduced through an Earthquake Hazards Reduction Program which includes state and local emergency management programs, and

WHEREAS, Congress included specific provisions in the Act to make assistance available to the states to further the purpose of the Act, yet states received for emergency management programs approximately 2% of FY87 appropriations, and

WHEREAS, the Federal Emergency Management Agency intends to further reduce this amount to approximately 1% by requiring states to provide 50/50 matching funds.

NOW THEREFORE, BE IT RESOLVED that the National Emergency Management Association representing the emergency management needs of the states and territories of the United States of America urgently recommends that:

1) the allocation in 100% federal funds to the states be increased from the present 2% to not less than 10% of the total National Earthquake Hazards Reduction Act appropriation in FY88, and that

2) the Congress reconsider present and future appropriations to emphasize practical application and to reduce emphasis on research in order to promote the development of state and local plans to respond to and recover from a catastrophic earthquake, and that

3) the proposed FEMA mitigation set-aside program be put on hold for further study and the funds for this activity be appropriated to state and local governments.

Unanimously adopted by the National Emergency Management Association in executive session March 11, 1987.

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

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6431 FAIRMOUNT AVENUE, SUITE 7, EL CERRITO, CALIFORNIA 94530-3624

CB

March 2, 1987

Honorable Doug Walgren
U. S. House of Representatives
Capitol Building
Washington, DC 20510

Dear Congressman Walgren:

I am writing as President of the Earthquake Engineering Research Institute (EERI) in support of reauthorization of the National Earthquake Hazards Reduction Act of 1977.

EERI is a professional society with over 1300 members concerned with earthquake hazard mitigation. Our members include architects, engineers, seismologists, geologists, building officials and other local government officials, urban planners, and other disciplines. There are both practitioners and researchers in our membership. EERI is a national organization with members in most of the 50 states.

I am sure that the accomplishments of the National Earthquake Hazards Reduction Program have been spelled out for you in great detail. I will highlight only a few:

- Research has led to development of better and more economical structures for resisting earthquake ground motions.
- Improved methods for evaluating and strengthening existing buildings.
- Improved public awareness and post-disaster plans.
- Better definition of the earthquake hazard in the United States through seismological and geological studies.

Much still remains to be done in all aspects of the earthquake hazard mitigation problem. These continuing needs are documented in the 5-year plan submitted to Congress by the Federal Emergency Management Agency. This is a good plan. At the same time, it is a minimum plan: several times the proposed amount could be spent efficiently to move rapidly toward a minimization of the earthquake hazard.

However, at least this minimum plan must go forward in order to continue progress toward improved public safety, to protect our national security and to prevent further deterioration of the competitive position of the American construction industry in international markets.

Sincerely yours,

Frank E McClure

Frank E. McClure
President

FMcC/bys

cc: Congressman George E. Brown, Jr.
2256 Rayburn House Office Building
Washington, DC 20510

Congressman Norman Y. Mineta
2350 Rayburn House Office Building
Washington, DC 20510

Ms. Carrye Brown
U. S. House of Representatives
Subcommittee on Science, Research and Technology
2319 Rayburn House Office Building
Washington, DC 20510

R. A. Olson
Earthquake Engineering Research Institute

CALIFORNIA INSTITUTE OF TECHNOLOGY

DIVISION OF ENGINEERING
AND APPLIED SCIENCE 104-44

25 February 1987

Honorable Doug Walgren, Chairman
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Subject: Reauthorization of National Earthquake Hazards Reduction Act of 1977

Dear Mr. Walgren:

I am writing to urge your support for the reauthorization of the Earthquake Hazards Reduction Act on which there will be Committee Hearings in the near future. The earthquake risk to life and property is increasing because of growth in population accompanied by increasing size of cities and increasing investment in buildings, lifelines, industrial facilities, etc. Public safety and reduction of property losses depend mainly upon the quality of earthquake engineering, and the quality of engineering depends upon earthquake engineering research which leads to improved safety and reduced cost of providing earthquake protection. Such research, which is funded through the Earthquake Hazards Reduction Act, will lead to important practical advances in resisting earthquakes. Studies of what can be expected from future U.S. earthquakes have shown deaths in the thousands, injuries in the tens of thousands, and property losses in the billions of dollars for a single event. Earthquake engineering research and its implementation can greatly reduce the expected consequences of future earthquakes.

I wish to call to your attention the following situation. The EHRA has two parts, earthquake engineering and earthquake prediction. The funding for the earthquake prediction is running at about 30 million dollars per year whereas the earthquake engineering funding has lagged and is running at about 15 million dollars per year. It is generally agreed that earthquake engineering is a very important element in an earthquake consequences reduction program and that this part of the Act is under funded.

Yours truly,

George W. Housner
GEORGE W. HOUSNER
Professor Emeritus

GWH:clb

PASADENA, CALIFORNIA 91125

Department of Civil Engineering

2340 G. G. Brown Building
Ann Arbor, Michigan 48109-2125
313/764-8495

College of Engineering
The University of Michigan

March 3, 1987

The Honorable Paul B. Henry
House of Representatives
502 Cannon House Office Building
Washington, DC 20515

RE: Reauthorization of the
National Earthquake Hazards Reduction Program (NEHRP)

Dear Representative Henry:

In October 1985 I sent a letter to you discussing the consequences of the Mexico earthquakes of 1985 to the USA earthquake hazards reduction efforts. Your kind response and information on the NSF National Earthquake Center RFP was appreciated. We did propose a CENTER at the University of Michigan but the NSF Center was awarded to New York.

The earthquake hazard is truly a national hazard and should not be thought of as a problem only for California Alaska, or New York. The Federal Emergency Management Agency five year plan provides for a balanced program to better understand the earthquake hazard throughout the United States, to develop a better understanding of the response of man-made structures to earthquake ground motion such as observed in Mexico City, and to assist the public in preparing their structures and themselves for a future earthquake.

Most regions of the midwest would rather ignore the earthquake hazard because it is easier and cheaper (in the short term) to do so. However this is poor public policy for which we will severely pay in human and financial suffering when the next midwestern earthquake occurs.

NEHRP has been one of the most cost effective and productive programs authorized by Congress. I urge your support and the support of your committee for the Reauthorization of the National Earthquake Hazards Reduction Program.

I would be pleased to discuss this program with you or a member of your staff at your desire and convenience.

Very truly yours,

Robert D. Hanson

Robert D. Hanson
Professor of Civil Engineering
(313) 764-5617

cc: Ms. Carrye Brown ✓

JN

JOHNSON & NIELSEN ASSOCIATES
CONSULTING STRUCTURAL ENGINEERS

Carl B. Johnson
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February 27, 1987

Honorable George E. Brown, Jr.
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Re: Reauthorization of the
National Earthquake Hazards
Reduction Act of 1977

Dear Congressman Brown:

On behalf of myself and a number of engineering colleagues, I would like to strongly urge you to vote favorably for the reauthorization of the National Earthquake Hazards Reduction Act of 1977. As you know, this program requires funding authorization by Congress every two years and a hearing is scheduled on March 10 by the House Committee on Science and Technology of which you are a member.

The funding made available by this Act from its inception in 1977 to date has made possible a considerable amount of much needed research and development in many areas of earthquake hazard mitigation. As an example, our firm has been involved in programs involving the development of improved earthquake design criteria for high-rise buildings in California, and a vulnerability study of the impact of a large magnitude earthquake on the Newport-Inglewood fault on the transportation, hospital and utility life-line system in the affected areas.

There are many on-going studies and numerous additional areas of research which require public funding to assist the engineering profession in its efforts to provide at least a minimum program of protection of the public from the effects of the ever-present earthquake hazard. Your Committee should be made aware that many members of the engineering professions, especially in California, have gladly devoted countless hours of efforts at no cost to the public over a period of many years in the development and promulgation of programs aimed at reducing earthquake hazards.

It is my sincere opinion that the amount of funding requested for this program is miniscule in comparison to many huge appropriations for questionable uses not only in our own country but all over the face of the earth.

Very truly yours,

Carl B. Johnson
CARL B. JOHNSON
Johnson & Nielsen Associates

CBJ/:ec

cc: Frank E. McClure, EERI, Pres.
Robert A. Olson, EERI
Ms. Carrye Brown, U.S. House of Representatives, Subcommittee on Science, Research and Technology

Englekirk & Hart
Consulting Engineers, Inc.

2116 Arlington Avenue
Los Angeles, California 90018-1398
(213) 733-2640

February 26, 1987

Honorable George E. Brown, Jr.
House of Representatives
Capitol Building
Washington, D.C. 20510

Dear Mr. Brown:

Over the last several years we have worked on a number of projects which have been funded by the National Science Foundation as part of the Earthquake Hazard Mitigation program.

These projects have all been concerned with the development of technically sound and commercially practical ways to reduce the seismic vulnerability of existing buildings. I view this work as among the most meaningful I have been involved in as it relates to public welfare. You must recognize that there is a very real possibility that thousands of Americans will die if a major Richter Magnitude 8 earthquake takes place in California.

I hope that you will support the National Earthquake Hazard Reduction Act's extension.

Very best regards,

ENGLEKIRK & HART, INC.

Gary C. Hart,
President

cc: Robert A. Olson, EERI

Ms. Carrye Brown
U.S. House of Representatives
Subcommittee on Science, Research and Technology
2319 Rayburn House Office Building
Washington, D.C. 20510

Los Angeles Honolulu Newport Beach Palo Alto Rome Seattle

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
Cornell University
HOLLISTER HALL, ITHACA, NY 14853-3501

February 27, 1987

Honorable Sherwood L. Boehlert
U.S. House of Representatives
Capitol Building
Washington, DC 20510

Dear Sir:

We strongly urge you to vote to continue the National Earthquake Hazards Reduction Act.

The Act was most effective in mobilizing a large segment of the earthquake engineering research community as well as engineers in design practice. The risks of major losses of life and property are great over most of the U.S., not only in some states. The new National Center for Earthquake Engineering Research (with headquarters in Buffalo) will make a strong impact on the development of new earthquake-resistant regulations and policies in New York State and throughout the nation. The NEHRA is an essential and basic component of this national effort.

All countries with high earthquake hazards (e.g., Japan, New Zealand, Taiwan, Italy, Canada) have substantial government support of research and code development. If anything, the funds from the U.S. government should be increased substantially to reduce the great risks.

We have a large group of engineers at Cornell University working on various aspects of earthquake engineering in cooperation with colleagues at a dozen other universities and with professional engineers. We have made significant progress but additional funding is essential to bring the results to fruition, to improve design practice, and to introduce regulations affecting critical structures (for example, hospitals, fire stations, pipelines, bridges, and tunnels).

Your support of the reauthorization of the Act will be greatly appreciated.

Sincerely yours,

Peter Gergely

Peter Gergely
Professor and Department Chairman
Structural Engineering

PG:nn

cc: Ms. Carrye Brown

Factory Mutual System

Allendale Insurance

Allendale Mutual Insurance Company
Allendale Park, P.O. Box 7500
Johnston, Rhode Island 02919

February 25, 1987

Honorable Claudine Schneider
U. S. House of Representatives
Capitol Building
Washington, D.C. 20510

Subject: Reauthorization of National Earthquake Hazards Reduction Act of 1977

Dear Representative Schneider:

I am writing to ask you to support reauthorization of the National Earthquake Hazard Reduction Act of 1977 for another two years.

The continued support of research in the area of earthquake disaster mitigation and hazards reduction is of vital importance in our efforts to deal with these events that have far-reaching effects on so many people.

You are probably familiar with the accomplishments of the National Earthquake Hazards Program; however, I will list just a few here:

There are much improved and better-tested methods for evaluating and strengthening existing buildings.

Research has led to development and use of better and more economical structures for resisting earthquake ground motions.

The earthquake hazard has been better defined in many areas through seismological and geological studies.

The private sector and government agencies have formed together to develop public awareness and post earthquake plans.

Even though a great deal of progress has been made in recent years toward the understanding of seismic issues, much additional research is needed.

Sincerely yours,

R W Greenlaw

Robert W. Greenlaw
Assistant Vice President

cc: Ms. Carrye Brown - House of Representatives ✓
Robert A. Olson - Earthquake Engineering Research Institute

RWG/md

COLLEGE OF ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

Bureau of Engineering Research · Phil M. Ferguson Structural Engineering Laboratory
10100 Burnet Road · Austin, Texas 78758-4497 · (512) 471-3062

February 26, 1987

Honorable Jim Chapman
U. S. House of Representatives
Capitol Building
Washington, DC 20510

Dear Mr. Chapman:

I am writing to support reauthorization of the National Earthquake Hazards Reduction Act of 1977.

Support for this program is important for the United States and for Texas. While Texas does not have a significant seismic exposure, research and teaching at Texas institutions of higher education is instrumental in training engineers who will be involved in design of earthquake resistant systems. Many large design firms in Texas are competing for contracts for professional services in which earthquake engineering expertise is essential. Perhaps of greater importance to Texas is the "spin-off" benefits from research supported by the National Earthquake Hazards Reduction Act. For the past 20 years, I have been engaged in research on the behavior of structures in earthquakes. Recent work on the repair and strengthening of structures damaged in earthquakes is now being applied to a variety of nonseismic problems.

Finally, the problem of earthquake hazards is truly national. In the event of a devastating earthquake in a high risk zone, Los Angeles for example, the entire country will be faced with rebuilding the damaged area. In our complex, interrelated economy and society, banking or communications systems which are damaged in Los Angeles could easily disrupt national networks and cause havoc in financial markets or other critical systems. Our national defense and supply networks are highly vulnerable to earthquake damage. I urge you to support this program so that the progress made in recent years is not lost and our understanding of earthquake-related phenomena continues to improve.

Sincerely yours,

James O. Jirsa
The Phil M. Ferguson Professor
in Civil Engineering
Director
Ferguson Structural Engineering Laboratory

JOJ:md
cc: Ms Carrye Brown ✓

350 Sansome Street
Suite 500
San Francisco, CA
94104

415 392 6952

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Henry J. Degenkolb
Thomas D. Wosser
R. Gordon Dean
Loring A. Wyllie Jr
Ted J. Canon
George E. Greenwood
Chris D. Poland
[illegible]

February 24, 1987

Honorable George E. Brown, Jr.
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Dear Congressman Brown:

As a structural engineer in California, I am writing to express my interest and concern about the Reauthorization of the National Earthquake Hazards Reduction Act of 1977. I hope that you will be able to give your full support for this act which is in the national interest.

Through the National Science Foundation, the Federal Emergency Management Agency and the U.S. Geological Survey, we have been able to make progress in researching the problems and providing defenses against the earthquake hazard. Our office has been involved with all three agencies as well as the National Research Council in helping to develop the NEHRP Recommended Provisions for the Development of Seismic Regulations for Buildings. We have visited the major damaging earthquakes in this hemisphere, as well as in Europe and Asia to see how the provisions have influenced building performance in major earthquakes. Most of this work has been voluntary.

The NEHRP act has permitted the cooperation of U.S. and Japanese engineers in the testing of the full-scale structures (seven-story concrete and six-story steel) and their various components, the results of which will reduce the hazards to many U.S. residents in the future. With the tentative predictions of major earthquakes in California in the next few years, especially in the southern part of the State, the continuation of the research and engineering studies becomes critical.

Also of concern is the necessity of continuing our research programs in order to maintain or regain our stature as leaders in aseismic design as compared to other countries in the Pacific Basin who are devoting a larger portion of their national production to earthquake research than we do. That leadership is important in maintaining construction activity in seismic areas outside of the U.S.

In summary, I would hope that you could give your full support to this measure, both for the benefit of the Nation and California.

Very truly yours,

Henry J. Degenkolb

HJD/dq

cc: Ms. Carrye Brown - Subcommittee on SR&T

Stevens Institute of Technology Castle Point, Hoboken, New Jersey 07030

Department of Civil and Ocean Engineering
201 • 420 • 5733

February 25, 1987

Honorable Robert G. Torricelli
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Re: Reauthorization of National Earthquake Hazards Reduction Act of 1977.

Dear Congressman Torricelli:

I am writing to strongly urge that you support the reauthorization of the National Earthquake Hazards Reduction Act of 1977.

The act was a major necessity at the time of its original passage and, unfortunately, it is still most urgently needed now. Although progress has been made in reducing hazards inherently connected with earthquakes (and many of these advances are attributed directly to support given by the above referenced act), the sad fact is that we still have a way to go before we can rest easily insofar as earthquake damage and destruction are concerned.

A continuation of the support offered by this act would permit an uninterrupted development of the necessary scientific-engineering research in this field. Incidentally, some of the significant contributions are being made by institutions and scientists in our state.

I sincerely hope you will support the reauthorization measure.

Very truly yours,

S.F. Borg
Professor of Civil Engineering

SFB:oap

cc: Ms Carrye Brown
U.S. House of Representatives
Subcommittee on Science, Research and Technology
2319 Rayburn House Office Building
Washington, D.C. 20510

JAMES T. P. YAO
PH.D., P.E.
201 EAST LUTZ AVENUE
WEST LAFAYETTE, INDIANA 47906

2/28/87

Honorable Lee H. Hamilton
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Dear Mr. Hamilton:

As a professor of civil engineering at Purdue University since 1971, I have worked on a number of research projects funded by the National Science Foundation through the National Earthquake Hazards Reduction Act. With these research grants, some twenty graduate students have been supported as research assistants to-date. These individuals have completed their graduate education and are now working for national laboratories, universities, and engineering companies.

Our research results have been dessiminated to the engineering profession in the form of technical reports and other publications. In addition, I have learned much by working with my students on these projects and thus have incorporated new knowledge into my courses, which are taught to all of my students at Purdue University.

Although we do not have frequent earthquakes in the State of Indiana, Our state is subject to earthquake hazards as evidenced by the 1811 earthquake of New Madrid, MO. It is necessary to continue both research and application to advance our knowledge. More importantly, we must educate young engineers to conduct earthquake engineering research. Therefore, your support to continue the National Earthquake Hazards Reduction Act will be gratefully appreciated.

Sincerely yours,
James T. P. Yao

xc: Honorable John Myers, Dan Quayle, Paul Simon; Ms. Carrye Brown; R.A. Olson; H.L. Michael

INTERTECT
International Disaster Specialists
P. O. Box 10502
Dallas, Texas 75207 U.S.A.
Tel.: (214) 521-8921

February 24, 1987

Congressman Lamar S. Smith
The U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Dear Congressman Smith:

In early April the Senate will decide whether or not to reauthorize the National Earthquake Hazards Reduction Act of 1977. I would like to take this opportunity to urge you to support reauthorization of the Act.

Since 1977, hundreds of activities have been supported under that Act. A number of those have included research activities which have greatly enhanced the state-of-the-art regarding earthquake prediction, earthquake mitigation, and post-disaster response and reconstruction. In a way, some of the research has showed us that "the more we know, the less we know". But a good deal has also resulted in practical measures that can be taken to reduce earthquake risk not only in the United States, but also internationally.

Despite the fact that Texas is not in an earthquake zone, a large number of researchers from our state universities, especially Texas A&M, the University of Texas, Rice, and North Texas State University have received support for major programs. In addition, a significant number of Texas-based private firms, such as ours, have also received direct support.

For all of these reasons, I strongly urge you to support the reauthorization of the National Earthquake Hazards Reduction Act.

Thanking you for your assistance in this matter, I am,

Respectfully,

Frederick C. Cuny

FCC:dg

cc: Ms. Carrye Brown
The U.S. House of Representatives
Subcommittee on Science, Technology and Space
425 Hart Senate Office Building
Washington, D.C. 20510

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

DEPARTMENT OF EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES
(617) 253-3381 Telex 92 1473

March 12, 1987

The Honorable Doug Walgren
Chairman, Subcommittee on Science, Research, and Technology
House of Representatives
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Walgren:

As one of several members of the scientific community involved in the study of earthquake hazards in the Northeastern United States, I am writing to express my concern about proposed budget cuts by the Nuclear Regulatory Commission which would directly affect our earthquake monitoring and research programs. The population density in the Northeastern U.S. and the number of nuclear power plants, as well as other critical facilities, are among the highest in the nation. Earthquakes in this area pose a serious threat, the implications of which are still not fully understood. To ensure that the power plants remain safe from this hazard, it is critical that the collection of regional earthquake data should continue.

An elaborate seismic network has been operating in the Northeast since 1975. Since 1980 it has been complemented by an Eastern Canadian network. The network stations were established at a great cost in terms of human effort and resources, and have been operating continuously and reliably until now. The primary reason for the existence of the Northeastern U.S. network has been to monitor earthquakes in order to understand earthquake risk for nuclear safety. This is important even if new power plants are no longer being constructed, because the existing plants are always subject to design review and upgrade.

We need to continue the operation of the networks for a simple reason. Without sufficient regional data we cannot understand the earthquake sources and their effects on structures in the Northeastern U.S. Because the earthquakes in this region occur less frequently than those in California, we need to accumulate data over a longer period of time before we can understand them. From the data obtained thus far we already know that earthquakes in the Northeast are significantly different from those on the West Coast: earthquakes of a given size generate much higher accelerations and cause much more damage in the Northeast than in California. We also know that the whole Northeast is seismically active, and that no location can be considered completely safe. We are fortunate that damaging earthquakes have not occurred recently in densely populated areas. Yet two earthquakes with magnitudes comparable to that of the devastating El Salvador earthquake of October 10, 1986 have occurred in the region since 1982.

Beginning in FY88 the Nuclear Regulatory Commission will start to channel the funds currently allocated to regional seismic networks to the U.S. Geological Survey, for the establishment of a National Seismic Network. When this national network is completed five years later, all NRC support for regional networks will be withdrawn, and the number of seismic stations in New England will have been cut from the current number of 50 down to about five. This small number of stations is not sufficient for studies that determine where and why potentially damaging earthquakes can occur. Due to budget cuts during the last few years, we cannot count on support from the U.S. Geological Survey. However it is critical for safety reasons to continue seismic monitoring and research on a regional level.

The enclosed report provides a more detailed description of earthquake hazards in the Northeastern U.S. It focuses in particular on New England earthquakes and on the primary institutions that operate the seismic networks in New England. We will be happy to answer any questions that you or your staff might have concerning this report or other regional networks. We would appreciate your support in this issue.

Sincerely,

Professor M. Nafi Toksoz
Director, Earth Resources Laboratory
Dept. of Earth, Atmospheric and
Planetary Sciences
Massachusetts Institute of Technology

Enclosure

cc: The Honorable Sherwood L. Boehlert, N.Y.

Earthquake Hazards in the Northeastern United States

Although the Northeastern United States (NEUS) is not as seismically active as California or Alaska, it faces a significant earthquake hazard. For example the 1755 Cape Ann, MA earthquake shattered chimneys in Boston and knocked debris into the streets, rendering them all but impassible. Other damaging earthquakes have occurred in 1727, 1925, 1940, 1982 and 1983 in various parts of the Northeastern U.S. The December 20 and 24, 1940 Lake Ossipee, New Hampshire earthquakes were both the same size (magnitude 5.4) as the October 10, 1986 earthquake that recently devastated San Salvador. Fortunately most of the recent New England earthquakes have been located in remote areas far from population centers.

Extent of possible damage:

While the western U.S. generally experiences more earthquakes than the eastern U.S., there is an important difference between eastern and western earthquakes. Seismic waves are much more efficiently transmitted through the rocks underlying the eastern U.S. than they are through the rocks in the western U.S. Thus an earthquake occurring in the eastern U.S. generally causes damage over a much larger area than a similar size earthquake in the western U.S. (see Figure 1). If we then consider that most of the population and the majority of nuclear power plants are in the East (Figure 2), it becomes apparent that the earthquake hazard in the East is quite significant.

Seismic networks in the northeastern U.S.:

Since about 1970 several institutions including Boston College and the Massachusetts Institute of Technology have been operating seismic monitoring stations in the NEUS. Beginning in 1975, these institutions have jointly published bulletins compiling locations and magnitudes of all recorded events. The current distribution of recording stations is shown in Figure 3. The data gathered by these networks have been of great importance in elucidating the pattern of earthquake activity in this region.

The resulting network seismicity (Figure 4) shows that, while the entire NEUS is characterized by diffuse earthquake activity, certain concentrations of epicenters stand out in particular. These include the New York City area, coastal New England, and northern New York State. Earthquakes in adjacent parts of Canada (Western Ontario and St. Lawrence river valley) can also cause damage in the NEUS.

Comparison of historic versus modern instrumental data:

There is a general correlation between the locations of recent and historic earthquakes (Figure 5). It appears therefore that detailed studies of well-located events that have occurred since the networks were established can provide an accurate picture of longer term seismicity in the NEUS. Differences between locations of recent earthquakes and historic epicenters can mostly be attributed to a population bias effect, in that historic locations were determined from felt reports.

Using the more recent network seismicity, however, we can get additional information not available from the historic record. First, we can estimate magnitudes of earthquakes with sufficient accuracy to compare the rate of seismic activity in this region during the past decade with rates of seismic activity in other parts of the world. Second, the relationship between earthquakes and specific geologic structures in this region can be analyzed using locations of earthquakes determined from the network data. These locations are generally accurate to within a few kilometers of the true epicenter. Third, the rate of decay of seismic energy with distance from an earthquake can be accurately determined using network recordings. This last capability is critical, because it can be used to estimate damage at a specific site caused by earthquakes occurring in various locations.

Association of earthquakes with active faults:

The information gathered from regional networks during the past 10-15 years has resulted in several research papers on NEUS earthquake characteristics. Earthquake monitoring and associated research need to continue in order to answer some questions that have arisen during the course of this work. For example, in California (and the western states in general) earthquakes are usually accompanied by visible ground displacement on active geologic faults. In the NEUS this is not the case. Thus it is necessary to rely on seismic network observations to investigate which geologic features are responsible for major earthquakes. The chances that a potentially damaging earthquake (magnitude 5 or greater) will occur somewhere in New England in a given year are about 1 in 20. By recording such earthquakes and their aftershocks with regional networks, information can be obtained about which geologic features might be associated with the events. Furthermore, because significant destructive earthquakes occur in the NEUS only every 100 years or longer, it is difficult to predict what the effects of such earthquakes would be without an in-depth understanding of the more frequently recorded moderate size earthquakes.

Site amplification:

Recent observations have demonstrated that another factor needs to be considered as well: the amplification by certain soil and rock types of seismic waves generated by large earthquakes, even those occurring 10's to 100's of miles away. For example, the September 19, 1985 Mexican earthquake, which was located off the west coast of Mexico, caused significant damage in parts of Mexico City, located more than 200 miles from the main shock. Thus, a large earthquake in the St. Lawrence river valley area, for example, could cause damage in the landfill areas of a city as far away as Boston. Only by studying the characteristics of seismic wave propagation across the

NEUS can this type of problem be examined. An understanding of the ground motion produced by distant earthquakes has important implications for the construction and maintenance of critical facilities such as nuclear power plants as well. These facilities can be affected by seismic energy generated by large earthquakes that do not necessarily occur directly beneath the structures. Further study of these effects is necessary, and depends on continued network operation.

Future of the networks: regional or national?

Currently regional seismic networks in the Eastern United States are funded primarily by the Nuclear Regulatory Commission (NRC). The total operational cost of these networks, including maintenance and data processing and analysis, is approximately $2.5 M per year ($1M for networks in the Northeast excluding phone line data transmission costs). Recently the NRC announced that this support for regional seismic networks will be phased out during the next 5 years, in the following way (A. Murphy, personal communication). After 1987, regional network contracts will be cut by 40%. This money will be spent on the establishment of a national network of seismic stations. The stations will be characterized by state-of-the-art instrumentation, data transmission via satellite, and a national data collection and redistribution center that would be accessible by phone line. The U.S. Geological Survey has agreed to supervise the establishment of this national network, and to take responsibility for its funding and maintenance after 1992. The NRC and USGS will be ironing out this agreement sometime before the end of 1986.

The new national network sounds like a good plan in many ways. It will provide upgraded equipment, rapid access by individuals of data from earthquakes occurring throughout the country, and uniformity in data and computer program formats. Unfortunately, however, the new national network is by no means a subsitute for regional networks. The termination of regional network operations would be a major loss for a number of reasons. First, the number of seismograph stations in the Eastern U.S. would be reduced from the current number of 250-255 (note that there are more than 750 stations in California alone) to 50-55 in the national network setup. In practice this means that stations will be 300-400 km apart. While it will be possible to detect magnitude 2.5-3 earthquakes with that configuration, it probably will not be possible to locate many of those events accurately enough to investigate what geologic features might be associated with them. Seismographs may be quite reliable, but they cannot all be counted on to work 100% of the time, so it is useful to have more than one instrument within 300-400 km. With the reduced number of stations many earthquakes will be missed.

Second, without the current regional networks, local expertise will be gone. A centralized system will not be able to respond quickly in the event of a moderate-sized earthquake (magnitude 4-6). This quick response requires an understanding of the earthquake in the context of previous seismic activity in the area. It also includes the ability to mobilize a team of local experts in order to reach the site of the earthquake within hours after the main event and record aftershocks using portable seismographs. The aftershocks provide very detailed information about the nature of the faulting that occurred during the earthquake. Because their rate of occurrence drops off exponentially with time, it is necessary to reach the field site as soon as possible. It is much easier for local network people to do this (and to have the interest in doing this type of study) because of their knowledge of the area, available transportation, experience with good recording sites, etc.

Third, during the transition period from the current recording and data processing system to the new national network, there will be a time during which the networks cannot operate due to funding cuts, and at the same time the new network will not be able to produce useful data because it will be new and untested.

Fourth, the regional seismograph networks are not only producing data that are absolutely essential for reliable seismic hazards analyses, but are also serving another useful purpose: to train young seismologists so that the country can have a steady supply of knowledgeable scientists able to deal with the interpretation of seismic records at close distances. This includes differentiating between earthquakes and artificial blasts (e.g., from quarries), understanding the effects of local cultural noise on the records, and knowing how local recording site variability affects the records.

Importance of a stable regional data base:

A number of government agencies have been supporting regional earthquake monitoring as well as related studies of hazard analysis, wave propagation effects, and earthquake sources. These include not only the NRC, but also the U.S. Geological Survey and the National Science Foundation. The Electric Power Research Institute has been contributing towards these studies as well. The recent effort to establish the Earthquake Engineering research center in Buffalo, N.Y., has demonstrated that there is a great deal of interest exhibited by eastern institutions in working on earthquake problems. Unfortunately in this period of budget cuts the trend is to focus only on areas that are currently experiencing high levels of seismicity, and on advancing our knowledge of earthquake engineering, particularly soil-structure interactions. These priorities are no doubt important , but it must be realized that studies in California or Taiwan cannot provide all of the information necessary to understand earthquakes in the Eastern U.S. and their effect on critical facilities or other structures. When a damaging earthquake occurs in the East within the next few years, we will be caught unprepared without regional networks.

It seems unwise to terminate these networks, which were developed and installed at a great expense both of manpower and money. Our recommendation is to maintain the regional seismic networks operating as they are currently, perhaps with some improvement in data exchange between networks. It is important that funding for regional networks be stable, so that seismologists in the NEUS can maintain a continuous data base for their research. The national network does need to be established as well, but not at the expense of what has been achieved already. Perhaps the increase in funding necessary to keep both projects going simultaneously can come from the U.S. Geological Survey, or from other government sources in addition to the NRC. Given the population density and number of critical facilities in the NEUS, however, we must not ignore earthquake hazards in this region.

Dr. Katharine Kadinsky-Cade, Earth Resources Laboratory, Massachusetts Institute of Technology.

Dr. Alan Kafka, Weston Observatory, Boston College.

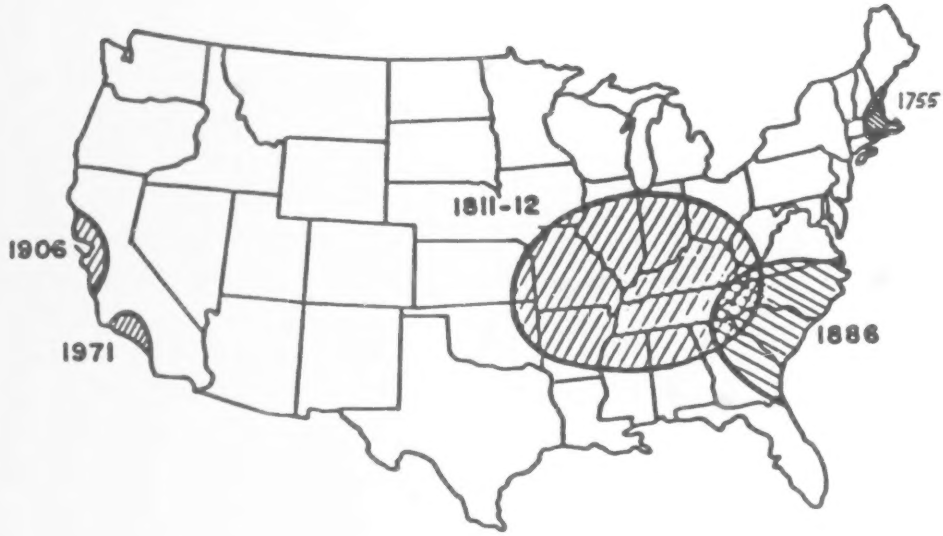
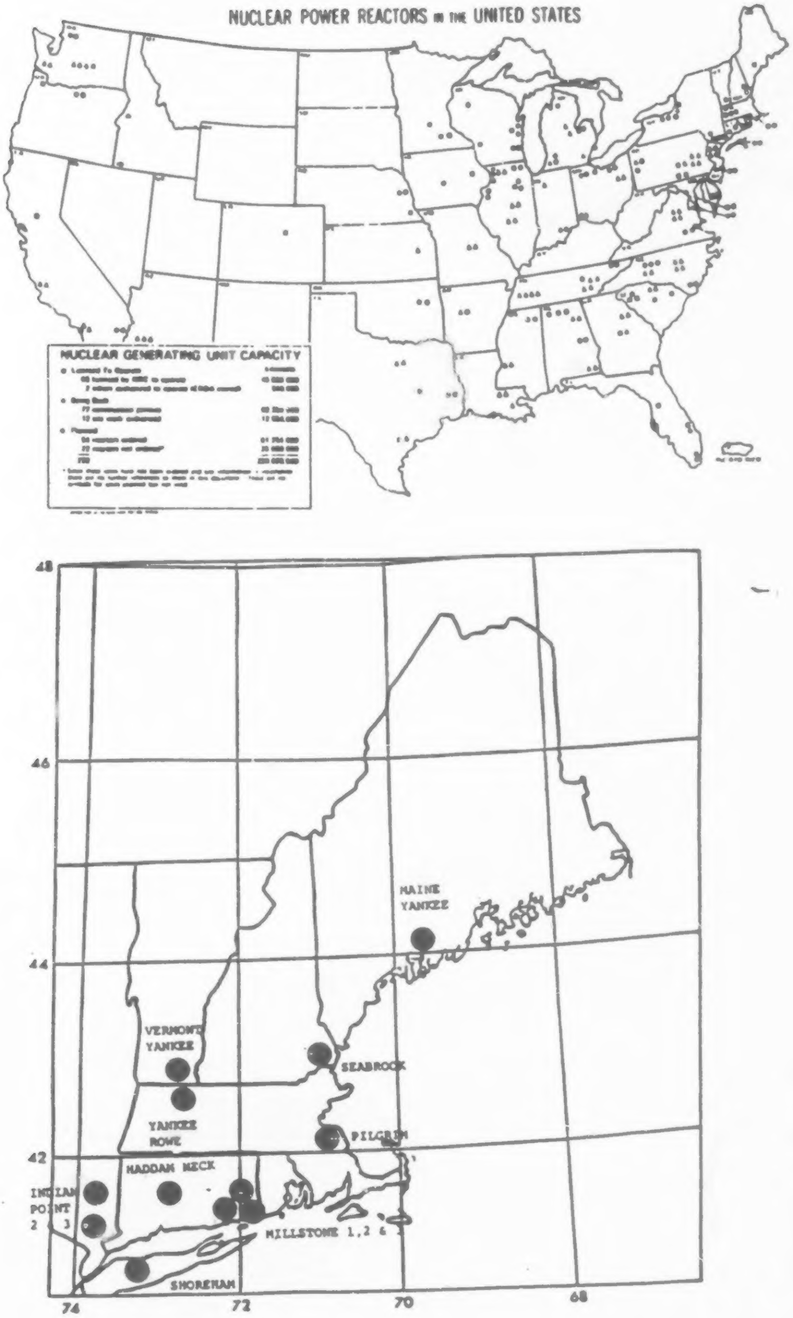


Figure 1: Comparison of felt areas during earthquakes: eastern versus western U.S. Contours outline areas that experienced intensities greater than VI on the Modified Mercalli scale. Intensity VI means earthquake felt by all, objects fall, many frightened. Magnitudes for the earthquakes shown are M=8 (1906 San Francisco; 1811-1912 New Madrid), M=6.5 (1971 San Fernando, 1886 Charleston) and 6.2 (1755 Cape Ann). Note that larger areas are affected in the East than in the West for an earthquake of given magnitude.


NUCLEAR POWER REACTORS IN THE UNITED STATES
NUCLEAR GENERATING UNIT CAPACITY
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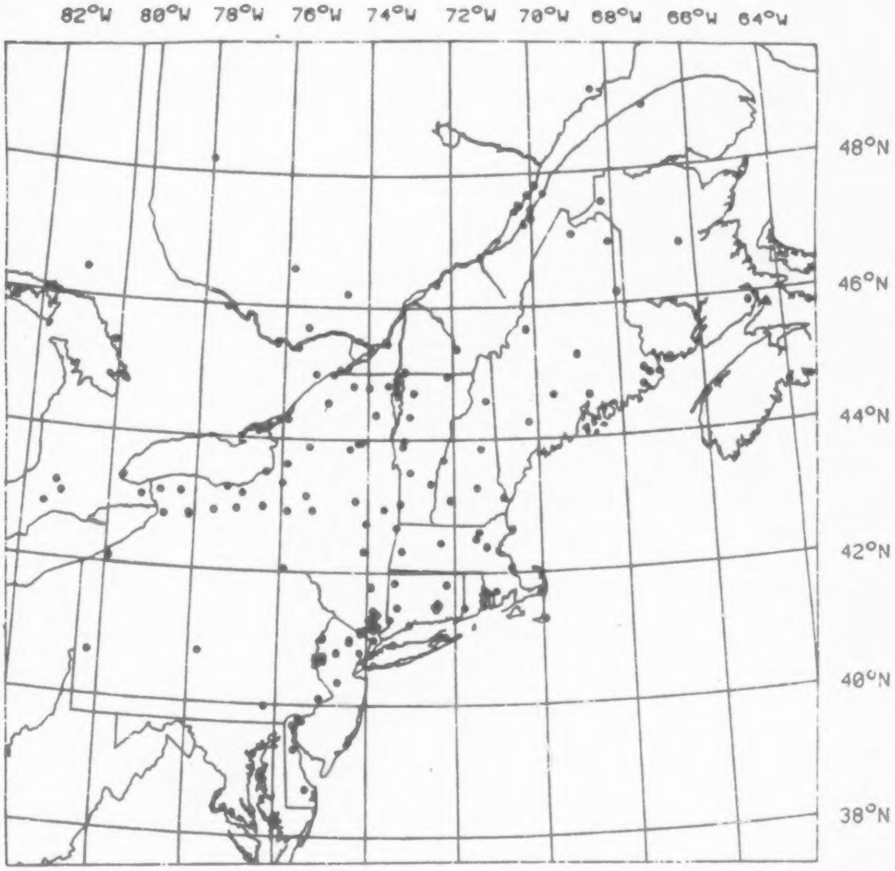
MAINE YANKEE
VERMONT YANKEE
SEABROOK
YANKEE ROWE
PILGRIM
HADDAM NECK
INDIAN POINT 2 & 3
MILLSTONE 1,2 & 3
SHOREHAM

Figure 2: *top* : Nuclear power reactors in the United States (after U.S. Dept. of Energy). Note the concentration in the eastern half of the country. *bottom* : Nuclear power plants in and immediately adjacent to New England.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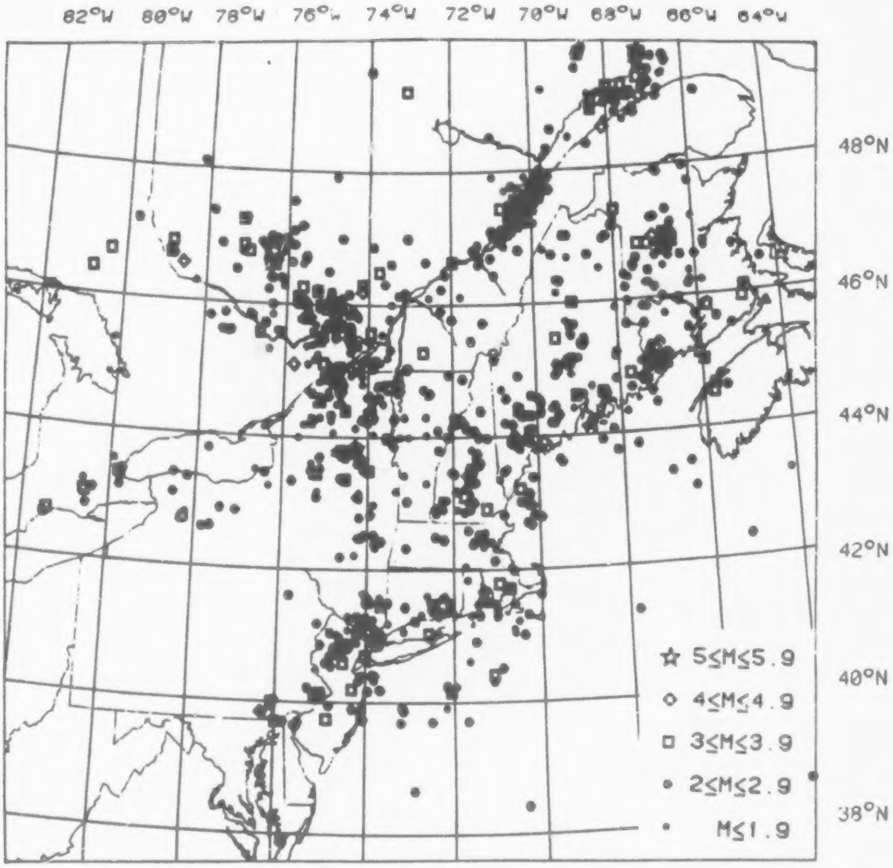
38°N

Figure 3: Seismic stations in the Northeast.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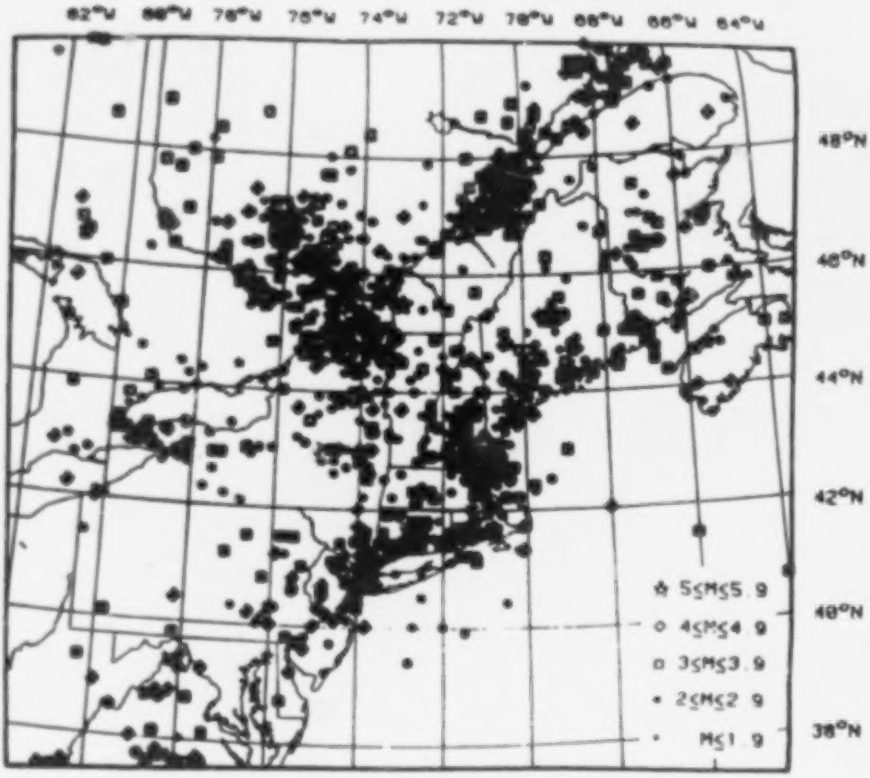
42°N
40°N
38°N
☆ 5≤M≤5.9
◇ 4≤M≤4.9
□ 3≤M≤3.9
● 2≤M≤2.9
• M≤1.9

Figure 4: Earthquake epicenters during the period October 1975-December 1984 These events were located using instruments from combined networks in the NEUS, shown in the previous figure.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☆ 5≤M≤5.9
○ 4≤M≤4.9
□ 3≤M≤3.9
• 2≤M≤2.9
· M≤1.9

Figure 5: Map of all historical earthquakes, from Chiburis (1981). The time period covered is from 1534 to 1975. All maximum epicentral intensities were converted to magnitudes for plotting purposes.

February 25, 1987

The Honorable Lloyd Bentsen
U. S. Senate
Capitol Building
Washington, D. C. 20510

Dear Senator Bentsen,

For the past six years, I have been supported by the National Science Foundation through the Earthquake Hazard Mitigation Program. Our research has involved the study of past earthquake ground motion and the findings have been used to formulate guidelines for seismic design of structures and facilities. Some of the findings were incorporated in a joint publication on the "Tentative Provisions for the Development of Seismic Regulations for Buildings", by the Applied Technology Council, the National Bureau of Standards, and the National Science Foundation. Such support is crucial to our educational and research programs.

I wish to urge you to support the extension of the National Earthquake Hazards Reduction Act of 1977.

Respectfully,

Bijan Mohraz
Professor Civil Engineering
and Chairman

cc: Mr. Pat Windham, U. S. Senate
Mr. Robert Olson, EERI

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SOUTHERN METHODIST UNIVERSITY / DALLAS, TEXAS 75275

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813 974-2581

Honorable Buddy McKay
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

February 20, 1987

Dear Representative McKay:

I am writing to express my interest and enthusiasm in the Reauthorization of the National Earthquake Hazards Reduction Act. I wish to encourage you to support this act which is of national interest.

Earthquakes are a major natural disaster which can devastate property and kill thousands. There is much yet that needs to be learned and incorporated into building codes to minimize earthquake damage. While Florida, to this date, has yet to suffer from a serious earthquake we can benefit from the knowledge obtained from the behavior of structures to dynamic loads.

High winds and ocean waves provide Florida with a dynamic loading environment which differ from earthquakes but still requires adequate knowledge of the response of structural members to rapid loading. Earthquake research has provided a better insight to the response of beams and columns to all types of dynamic loads. The behavior of structural members to rapid loading can and is of benefit to Florida engineers and residents.

May I again encourage you to support the reauthorization of the National Hazard Reduction Act.

Sincerely Yours

Bruce A. Suprenant

Bruce A. Suprenant, Ph.D., P.E.
Associate Professor

cc: Ms. Carrye Brown (Subcommittee on Science, Research and Technology)

Mr. Robert A. Olson (Earthquake Engineering Research Institute)

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5751 Palmer Way
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619/438-5899

Herman O. Ruhnau, FAIA
David Ruhnau, AIA
Gary L. McGavin, AIA

March 2, 1987

Honorable George E. Brown, Jr.
U.S. House of Representatives
Capitol Building
Washington, D.C. 20510

Dear Congressman Brown:

Our firm has recently completed a study on the Operability of Life Support Equipment in Hospitals after an earthquake. This research project was funded by the National Science Foundation through the Earthquake Hazard Mitigation program. Studies such as this will most certainly help save many lives through implementation of the recommendations established by our report and similar studies being conducted by others.

A great deal of progress has been made in understanding nonstructural seismic issues in recent years. There is a large amount that we do not yet know. Research funded through programs such as the Earthquake Hazard Mitigation program is vital to furthering our knowledge. We urge you to continue to support the National Earthquake Hazards Reduction Act of 1977.

Sincerely,

Gary L. McGavin, AIA, of
RUHNAU McGAVIN RUHNAU/ASSOCIATES

GLM/mjf

4-50-01

Enclosure

cc: Roger Scholl, EERI
Ms. Carrye Brown

61 San Mateo Road,
Berkeley, CA 94707
23 March 1987

RECEIVED
MAR 26 1987
COMMITTEE ON SCIENCE
AND TECHNOLOGY

Subcommittee,
House Science & Technology
House Office Building
Washington, D.C. 20515

Dear Sirs and Ms.:

Much more needs to be done now, during nonemergency times, to plan to alleviate the suffering after the inevitable earthquake which California and other areas will have.

Government grants to local areas should stipulate continuous planning for disasters as a condition for the grants.

Government agencies in local areas should do more that just give lip-service to disaster planning.

Each large firm or office building should be required to have drills and to stockpile supplies that may be needed for self-care immediately after a large quake.

Transportation agencies should be required to do extensive planning to handle the massive problems of clearing the streets of debris, coordinating rescue efforts, providing alternate routes to travel, restricting unessential travel, etc. Use of bicycles as the main mode of local transportation in some areas may need to be anticipated.

Local building inspection agencies should be required to condemn hazardous buildings which should be razed as soon as possible.

Other hazardous sites, such as areas where subsidence and liquefaction are likely, should be determined and plans made to alleviate the damage.from a major quake.

In summary, there is much to be done now while it can be done with careful planning and full consideration of the alternatives.

Yours truly,

Charles Smith

Charles L. Smith

Just in Case

EVERYONE'S GUIDE TO DISASTER PREPAREDNESS AND EMERGENCY SELF-HELP

by
John Moir

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HOW TO PREPARE FOR A DISASTER

WHAT TO EXPECT IN A DISASTER

We are accustomed to a life of convenience that would seem unbelievable to someone who lived just a hundred years ago. And yet, the marvels of modern technology are often the first things to be swept away by a disaster. Many emergencies temporarily interrupt the electric, water, sewer, communication and transportation systems upon which our present way of life depends. When this occurs, we are left to grapple with unusual problems and difficulties.

It is vital to realize that help may not be rapidly forthcoming. No matter how well-organized the relief effort, it frequently takes from several hours to as much as a few days before help arrives and services are restored. Therefore, your ability to be self-sufficient is of critical importance. How well you fare depends largely on your plans, preparations and knowledge.

THE BASICS OF DISASTER PREPAREDNESS

1. *Planning And Preparation*—Most people spend hundreds of dollars each year on various forms of insurance. How many, however, have made the necessary preparations to develop their own "disaster insurance plan"? It's easier than might be imagined. The premium costs you some time and a relatively small outlay of money. The benefit you receive is the ability to safeguard your family and home from most disasters in the best way possible.
2. *What To Do In An Actual Disaster*—If a disaster strikes, you need to have good, solid knowing about the disasters that may occur in your area, when they most often happen, and how to protect yourself from them. If you do much traveling, it's also a good idea to have at least a basic understanding of disasters that strike in other parts of the country.
3. *How To Handle A Disaster's Aftermath*—The critical time following a disaster, when public services are limited or non-existent, is likely to pose unusual problems. Having the knowledge to deal with these will make things easier and, in many cases, save needless worry and effort.
4. *First Aid*—You may have to rely on your own first aid skills during an emergency. To prepare for this possibility, you should have a first aid kit suited to your own particular requirements. Furthermore, the ability to give first aid in a disaster can be a lifesaver.

Chronicle Books
870 Market Street
San Francisco, CA 94102

Discussion of the Need for Disaster Planning at Caltrans

A few proposals by Charles Smith, citizen

Now while the logistics and time pressures are not pressing would be a good time to undertake some of the simple steps that would greatly reduce the problems when and if an earthquake disaster happens.

1. All employees should be informed as to their responsibilities and course of action during and after an earthquake.
2. Separate instructions should be developed, depending upon whether the quake happens during working hours or on evenings or weekends.
3. An inventory of each employee's skills, home location, and equipment should be made and kept up to date. A computer program should be developed so that the data will be readily accessible to persons needing that data during a crisis.
4. All state vehicles should be outfitted with certain basic tools and equipment which will be ready to use wherever a vehicle may be after a quake. Maintenance vehicles now have much of the equipment, including radios, but they should be reviewed and supplemented where needed.
5. Design, retrofitting, and construction of freeways, bridges and support facilities should be considered with the problems of recovery from an earthquake in mind:

   Between each two interchanges or bridges on freeways there should be specific analysis of the potential problems if either one or both of the structures are un useable or block the freeway.

   Access from one side of the freeway to the other through the median may need to be provided and actually accomplishe by the persons who happen to be on the site.

   Access to the frontage roads may need to be planned---with ramps and gates through the fences at particular locations. The problem of rain and soggy soil should be considered.
6. Subsidence of freeways on filled land on or in low areas should be considered. Berms or dikes to prevent intrusion of water could be built now at optimum cost, depending upon proximity of the borrow area or construction site.
7. Alternate routes need to be planned.
8. Stockpiling, with a current inventory, should be a basic preparation for disaster.
9. Liaison with other agencies now, supplemented by practice drills, is very necessary for a minimum of confusion when the need presents itself.
10. Each employee should probably be required to take the basic Red Cross courses in first aid.
11. Plans for traffic control after a disaster are much needed. Prevention of traffic jams, smooth functioning of intersections, restriction of non-essential traffic, and related problems should all be anticipated. Among the items that each State employee and vehicle should have is the traffic whistle which will come in very handy when it is needed.
12. Through the procedures and plans that Caltrans does now, other agencies and firms may be encouraged to do also. The sound planning and training that we do will go far to both create confidence in government and reduce the problems after a major earthquake.

Transportation is the key to recovery from a major earthquake. Planning and preparation now are absolutely essential.

Just in Case

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by
John Moir

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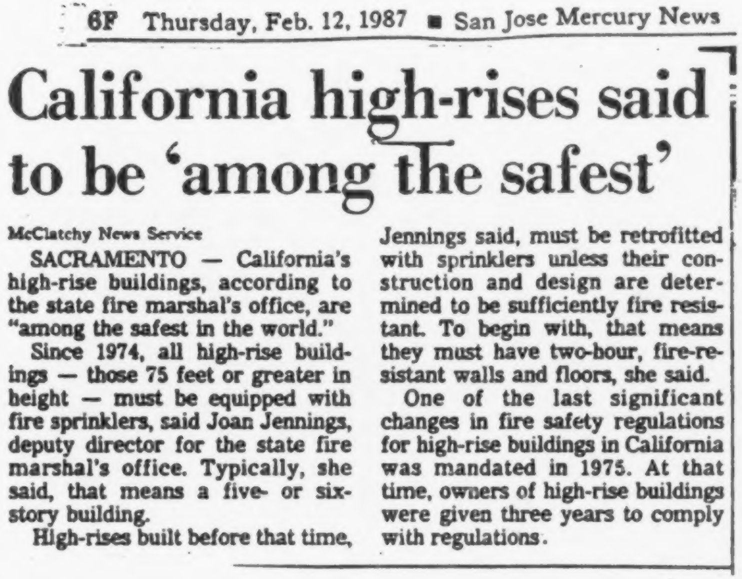


6F Thursday, Feb. 12, 1987 ■ San Jose Mercury News

California high-rises said to be 'among the safest'

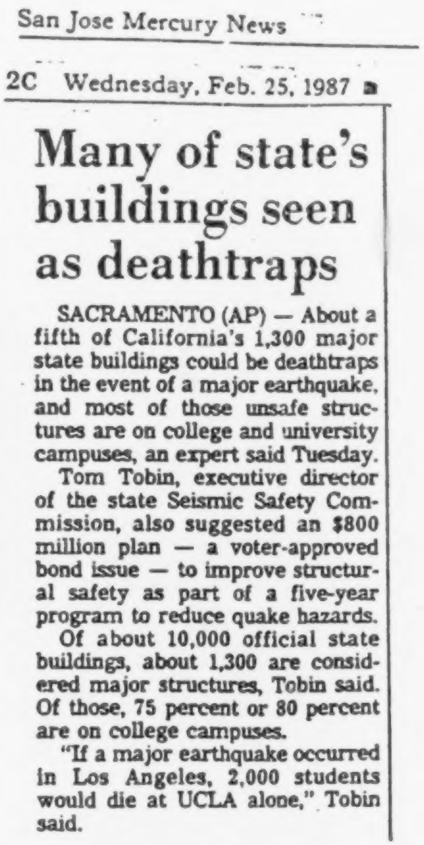
McClatchy News Service

SACRAMENTO — California's high-rise buildings, according to the state fire marshal's office, are "among the safest in the world."

Since 1974, all high-rise buildings — those 75 feet or greater in height — must be equipped with fire sprinklers, said Joan Jennings, deputy director for the state fire marshal's office. Typically, she said, that means a five- or six-story building.

High-rises built before that time, Jennings said, must be retrofitted with sprinklers unless their construction and design are determined to be sufficiently fire resistant. To begin with, that means they must have two-hour, fire-resistant walls and floors, she said.

One of the last significant changes in fire safety regulations for high-rise buildings in California was mandated in 1975. At that time, owners of high-rise buildings were given three years to comply with regulations.



San Jose Mercury News

2C Wednesday, Feb. 25, 1987 ■

Many of state's buildings seen as deathtraps

SACRAMENTO (AP) — About a fifth of California's 1,300 major state buildings could be deathtraps in the event of a major earthquake, and most of those unsafe structures are on college and university campuses, an expert said Tuesday.

Tom Tobin, executive director of the state Seismic Safety Commission, also suggested an $800 million plan — a voter-approved bond issue — to improve structural safety as part of a five-year program to reduce quake hazards.

Of about 10,000 official state buildings, about 1,300 are considered major structures, Tobin said. Of those, 75 percent or 80 percent are on college campuses.

"If a major earthquake occurred in Los Angeles, 2,000 students would die at UCLA alone," Tobin said.

THE NEW YORK TIMES, SUNDAY, MARCH 8, 1987

We Need Evacuation Plans for Other Risks Than Nuclear Plants

To the Editor:

You are right to call for a reinstatement of the authority of the Federal Government over emergency planning ("Federal Power Over Nuclear Power," editorial, Feb. 9). But there is another issue at stake, and that is the incredible inconsistency in the furor surrounding the establishment of evacuation plans for nuclear plants, but not for any other facilities of comparable risk.

Accidents involving major chemical facilities, gas and oil storage sites, and dams, to mention only a few, pose risks similar to, and often greater than, nuclear power plants. In another example, the much heralded high-tech activities for semiconductor production (often billed, ironically, as a clean technology) involve storage of large quantities of extremely toxic chemicals, which, in the event of accident or earthquake, could lead to disaster, according to a report from California (news story, Feb. 8).

Nuclear power plants do not pose unique risks either in probability or potential impact. Bhopal — far more serious in its impact than Chernobyl — amply illustrates that. But there are domestic examples as well.

In 1976, the Grand Teton Dam failure was, fortunately, limited in impact to fewer than a dozen fatalities (although more than $500 million in damages was claimed). A dam failure in Italy killed more than 2,000, and there are several dams in the United States that put at risk hundreds of thousands of people.

Even the prosaic railroad industry poses significant risks in the transport of hazardous materials, with accidents commonly leading to sudden evacuations. For example, more than 250,000 people were evacuated from a Toronto suburb a few years ago because of a chlorine rail-car derailment.

There are very good reasons for a state government to facilitate the establishment of sensible and effective emergency plans for all types of facilities and accidents. In seeking to eliminate nuclear plants by setting impossible standards for emergency preparedness, what states ignore is that such plans can serve as models for other facilities. A number of utility nuclear emergency plans have already been implemented to respond to situations entirely unrelated to the power plant.

GILBERT BROWN

Lowell, Mass., Feb. 24, 1987

The writer is a professor in the University of Lowell College of Engineering.

01854

The Times welcomes letters from readers. Letters for publication must include the writer's name, address and telephone number. Because of the large volume of mail received, we regret that we are unable to acknowledge or to return unpublished letters.

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Central United States
Earthquake Consortium

Post Office Box 367, Marion, Ill. 62959 ☐ (618) 997-5659

NEWS RELEASE

E. Erie Jones, Executive Director March 18, 1987

SEISMIC AND ENGINEERING RESEARCH RESOLUTION, POLICY STATEMENT II

The Central United States Earthquake Consortium has adopted a resolution to support the development of an earthquake detection and estimation system, and earthquake-related research in the central United States.

The Consortium is a non-profit, federally funded corporation whose board of directors is comprised of emergency services directors from the seven states most affected by the New Madrid Seismic Zone: Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri and Tennessee. Among its primary responsibilities is lessening risks to property and life that could result from seismic activity in numerous earthquake faults that lie within the Consortium states.

Erie Jones, CUSEC executive director, said that nationally respected scientists and engineers have presented convincing evidence that the central United States suffers from a lack of scientific information regarding earthquakes and the sophisticated equipment necessary to produce it. The resolution specifically targets the need for seismological data on earth motion and its effect on man-made structures.

St. Louis University seismologist Otto W. Nuttli, who is regarded as the foremost authority on seismicity in the CUSEC region, says that the present strain level in the New Madrid fault zone could produce an earthquake of magnitude 7.6 were it released today. The figure was adopted by the CUSEC Board of Directors in October 1985 as the basis for earthquake preparedness planning in the seven states.

Arch Johnston, director of the Tennessee Earthquake Information Center at Memphis State University, said the region has already passed the "average return time" for an earthquake in the magnitude 6 and 7 range. "I can't call that overdue because it is an average," he said, "but the return period is about 70 or 80 years, and it has already been 92 years since the last one."

Nuttli and Johnston agree not only on the likelihood of damaging earthquakes occurring in the CUSEC region. They both are adamant that seismographic instruments are needed to define the boundaries of probable earthquakes, to determine their frequency of occurrence, and to allow for accurate estimates of damage and hazards based on probability.

While there is seismographic equipment in the region, Johnston said the present system needs to be expanded and updated, taking advantage of new technologies. Recording of ground motion is spotty and sometimes imprecise, and scientists have occasionally been unable to determine which of the region's many faults was the source of an earthquake, he said.

Of particular concern is the recent announcement that the Nuclear Regulatory Commission may shut down its seismographic network because the funding to maintain it is expected to be reduced or eliminated by 1990.

"You need decades to accumulate a quality data base," Johnston said. "Now that we have laid the foundation, we are cutting our own throats to abandon the system when we are just getting started."

"We need some of this information very badly, especially if we want to predict what the bigger earthquake is going to do to the central United States," Nuttli said. "The longer we can operate instruments, the more likely we will get data we need, which we don't have at the present time."

Seismographic instrumentation is not only sparse, but some is also inadequate. "We need broad-band instruments," Nuttli said, "that will measure higher and lower earthquake-wave frequencies." He estimates that each new installation of sophisticated seismographs would cost about $50,000.

The need for strong-motion instruments to measure the reaction of structures to earth movement is equally acute. Mete A. Sozen, professor of civil engineering at the University of Illinois, said that engineers need data to improve structural design and construction. Only a few strong-motion instruments exist in the Central United States Seismic Zone, and most are placed on dams, with a few in veteran's hospitals.

"We must understand the hazards of and our vulnerability to earthquakes better," Jones said. "We have the expertise in the central United States to produce the necessary techniques and data," he said, "but we must have funding to support it."

Jones expects the Seismic and Engineering Research Resolution, which was enacted by the CUSEC Board of Directors in November 1986, to influence the direction of funding for equipment and research, and to create a greater awareness of the earthquake risk.

"The resolution sets an irreversible course," Jones said. "Making residents aware that they should get under tables and stay inside when an earthquake occurs is one aspect of preparedness, but truly effective mitigation planning must be done before the emergency on a large scale."

Central United States
Earthquake Consortium

Post Office Box 367 Marion IL 62959 □ (618) 997-5659

Policy Statement II
of November 18, 1986

Early in the corporate life of the Central United States Earthquake Consortium, the Consortium initiated a continuing series of public awareness conferences involving audiences of diverse interests. During this same time period, technical meetings with engineers, seismologists, geophysicists and geologists were convened and attended by people of the CUSEC area.

From these information-gathering opportunities, a series of evident multidisciplinary needs emerged, which CUSEC desired to address as part of its mission commitment.

Deliberations by the CUSEC Board of Directors, in concert with efforts by distinguished representatives of the several appropriate disciplines, resulted in adoption of the following policy resolution by the board.

Seismic and Engineering Research Resolution

> *At a regularly scheduled annual meeting of the Central United States Earthquake Consortium Board of Directors in November 1986, the following resolution was enacted unanimously:*

Whereas the Central United States Earthquake Consortium is concerned that seismic research, seismic hazard research, and seismic engineering research in the Central United States are neglected and underfunded at the federal level, and

Whereas the instruments and facilities of the in situ federally supported seismographic networks in the Central United States region need to be sustained and upgraded to provide important and basic necessary data, and

Whereas the current techniques for seismic hazard estimation in the CUSEC region are at a rudimentary level and need to be improved in the area of earthquake physics, earthquake location, size, ground motion scaling, and site-specific seismic effects, and

Whereas there is a need for the development of new techniques for the rapid assessment of site properties for use by the geotechnical and engineering communities, and

Whereas a CUSEC seismic hazard technical handbook providing state-of-the-art seismicity maps and initial probabilistic estimates of degree of ground shaking would be of great benefit to the people of the Central United States, and

Whereas current instrumentation falls far short of that required to gain maximum scientific data from the rare, large Central United States earthquake, and

Whereas there is a particular and severe deficiency of strong motion instrumentation installed on selected buildings of the major metropolitan areas subject to seismic risk required to record dynamic response data to major occurring earthquakes, and

Whereas the methods for developing the vulnerability assessment on various types of existing construction needs to be further developed for maximum efficiency in the mitigation of structural damage, and

Whereas there is need to develop cost-effective methods of reducing the seismic risk to buildings now more than ever before, and

Whereas specification of data acquisition and instrument deployment needs for on-scale, full bandwidth recording is sorely needed, and

Whereas there is a need for an improved, large scale set of seismic hazard maps for the Central United States with seismicity, liquifaction and slope stability overlays, and

Whereas a guidebook suitable for engineering use for site-specific seismic analysis for design/construction is needed to detail the state-of-the-art techniques based on microzonation studies of population centers and liquifaction/slope stability of rural areas, and

Whereas field studies will be needed in the CUSEC region to provide both the near surface soil data and the upper crustal attenuation data to accurately specify site-specific potential ground shaking,

Whereas there is a widely perceived need for the seismic evaluation of water and sewer infrastructures of all portions of the Central United States, particularly in the major metropolitan areas, to procure information necessary to improve the readiness of these systems when major earthquakes occur, and

Therefore, be it resolved that existing federally supported seismographic networks in the CUSEC region should be continued, enhanced and expanded to meet the scientific objectives to support the Central United States Earthquake Consortium's broad mission of reducing seismic risk in the Central United States, and

Be it further resolved that funding for future seismic research in the Central United States be advisedly directed to programs of application value to those perceived needs as outlined herein, and

Be it further resolved that the concerns herein expressed be shared with the decision makers of the executive and legislative branches of the United States, and

Be it further resolved that each public and each community with which the Consortium communicates be advised of the herein contained serious concerns.

Adopted unanimously this 18th day of November 1986 by the Central United States Earthquake Consortium at the annual meeting of the board of directors in Collinsville, Illinois.

E Earl Jones
E. Erie Jones
Executive Director

Attest Wilbur R Buntin J
Wilbur R. Buntin
Chairman

January 18, 1987